BASIN ANALYSIS AND PETROLEUM PROSPECTS OF THE LARAPINTA GROUP, AMADEUS BASIN, WITH PARTICULAR REFERENCE TO POROSITY EVALUATION

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by

Leszek Edward KURYLOWICZ

Department of Geology,
Canberra.

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AUTHOR'S STATEMENT

I declare that the research described in this thesis is my own except where the work of others is specifically acknowledged.

Leo. Kurylowicz

L.E. Kurylowicz

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ABSTRACT

The Upper Cambrian to Upper Ordovician Larapinta Group of the Amadeus Basin, Central Australia, comprises the basal Pacoota Sandstone, overlain successively by the Horn Valley Siltstone, the Stairway Sandstone, the Stokes Siltstone, and the Carmichael Sandstone.

Palinspastic reconstruction of the Amadeus Basin at the end of Larapinta Group deposition indicates that the sediments have been compressed by an average of 12.4% of their original length (in a south-southeasterly, 200°, direction).

Restored isopach and lithofacies maps were constructed using the derived palinspastic base map.

A porosity study of the arenaceous members of the Larapinta Group indicates that porosity values in the Pacoota Sandstone increase from about 4% in the Palm Valley area to about 12% in the Alice No. 1 area to the east. The porosity values also increase to about 10% in the Mereenie area to the west, and to about 12% in AP3 well in the south. In the Stairway Sandstone porosity values, as well as total storage capacity (average porosity x net porous thickness), increase in a southerly direction. Thus a trend of southerly increasing porosity is postulated for the two formations.

Growth of authigenic silica, which is related to the overburden thickness and proximity to the basin's northern margin, is postulated to be the main cause of porosity variation in the basin. Removal of overburden in the east during the Rodingan Movement (Silurian) caused fracturing and provided for better secondary porosity development, particularly in the Alice No. 1 area.

Good source rocks and hydrocarbon-generation conditions existed in the Horn Valley Siltstone and middle unit of the Stairway Sandstone. It is estimated that the known reserves of oil and gas in the Mereenie and Palm Valley Fields account for all the hydrocarbon-yield potential of the Horn Valley Siltstone and middle unit of the Stairway Sandstone. Additional hydrocarbon accumulation depends in part on the source rock potential of shales within the Pacoota Sandstone, and possibly also on the source rock potential of the Stokes Siltstone. All of the anticlines exposed at the surface but unbreached within the Larapinta Group have been drilled. The remaining traps (mostly fault-blocks associated with anticlines) have been delineated by seismic traverses. The dimensions (areal and vertical closures) of the remaining traps are smaller than either the Mereenie of Palm Valley Fields. The prospect of their being drilled depends upon economic factors. Stratigraphic traps may occur in the east (Ooraminna area), in the centre of the basin (Gardiner Range) and in the south (Seymour Range area) where convergence of beds is noted.

1. INTRODUCTION

Research for the thesis was carried out largely in the author's own time over a period of two and half years under the supervision of Dr C.E.B. Conybeare of the Department of Geology, Australian National University.

Petrophysical analyses of the Palm Valley and Mereenie field wells, which were the product of the author's normal work at the BMR under the supervision of Mr M.C. Konecki, have been incorporated in the thesis.

Wireline logs, core analysis results, and core and cuttings descriptions from twenty five petroleum exploration wells and four BMR phosphate boreholes were used in the porosity study which also included detailed petrographic analyses of seventy six thin sections to determine the causes of porosity variations.

Stratigraphy of the Larapinta Group was compiled from BMR and private exploration company data, the latter made available by the courtesy of Magellan Petroleum (N.T.) Pty Ltd and Oilmin N.L.

2. BASIN DEFINITION

The Amadeus Basin is an east-west trending elongate downwarp covering an area of about 145 000 km^2 (56 000 sq miles) in the Northern Territory; only a small part of the basin extends into Western Australia (Plate 1). It contains Adelaidean, Cambrian, Ordovician, Silurian?, Devonian, and Carboniferous? sediments resting unconformably upon predominantly crystalline Precambrian basement rocks (Wells et al. 1970). The basement consists of all rocks older than the Adelaidean Heavitree Quartzite.

The southeastern extension of the Amadeus Basin beneath the Eromanga and Pedirka basins (Warburton Basin) is poorly known as is its westerly and northwesterly extension beneath the Canning Basin. At present the eastern and western margins are defined by the outcropping unconformable contacts with the younger basins (Forman et al. 1973).

3. REGIONAL STRATIGRAPHY

Approximately 9000 m (30 000 ft) of sedimentary rocks are preserved in the basin (Table 1). The Adelaidean succession consists of a basal quartzite sequence and a dolomite, siltstone and evaporite. The sequence remains largely unchanged throughout the basin. Above the Adelaidean is a varied sequence of continental, paralic and glacioaqueous sediments which is about 4500 m (15 000 feet) thick in the south-central part of the basin. The only known volcanics, interbedded with the dolomite siltstone and evaporite sequence, occur in the northeast and southwest.

Extensive folding and overthrusting of the basement and the sedimentary cover during the Petermann Ranges Orogeny late in the Precambrian or early in the Cambrian, uplifted the southwestern margin and gave it its present form. During the orogeny the competent Adelaidean strata were detached from the underlying strata and slid northwards on a décollement surface.

The Cambrian sediments unconformably overlie the Adelaidean in the southwest and conformably in the northeast. The sediments consist of red, fluvial cross-bedded sandstone adjacent to an ancient shore-line in the south and southwest, and of marine shale and carbonate to the northeast.

The middle Upper Cambrian to Upper Ordovician rocks comprise interbedded thick marine orthoquartzite and shale and the Silurian? to Carboniferous? rocks include continental (or transitional) orthoquartzite and continental red - beds. Diastrophism and erosion at the end of the Ordovician and in the Late Devonian resulted in gentle angular unconformities adjacent to the present northern margin of the basin. The strongest diastrophism occurred during the Alice Springs Orogeny in the Carboniferous, when thrusting occurred through the crust in the northern margin; nappes involving basement and cover rocks grew at places along the northern margin, and the sedimentary rocks within the basin were transported southward over two surfaces of detachment and became folded. One surface of detachment lies within the Adelaidean dolomite-siltstone-evaporite sequence and the

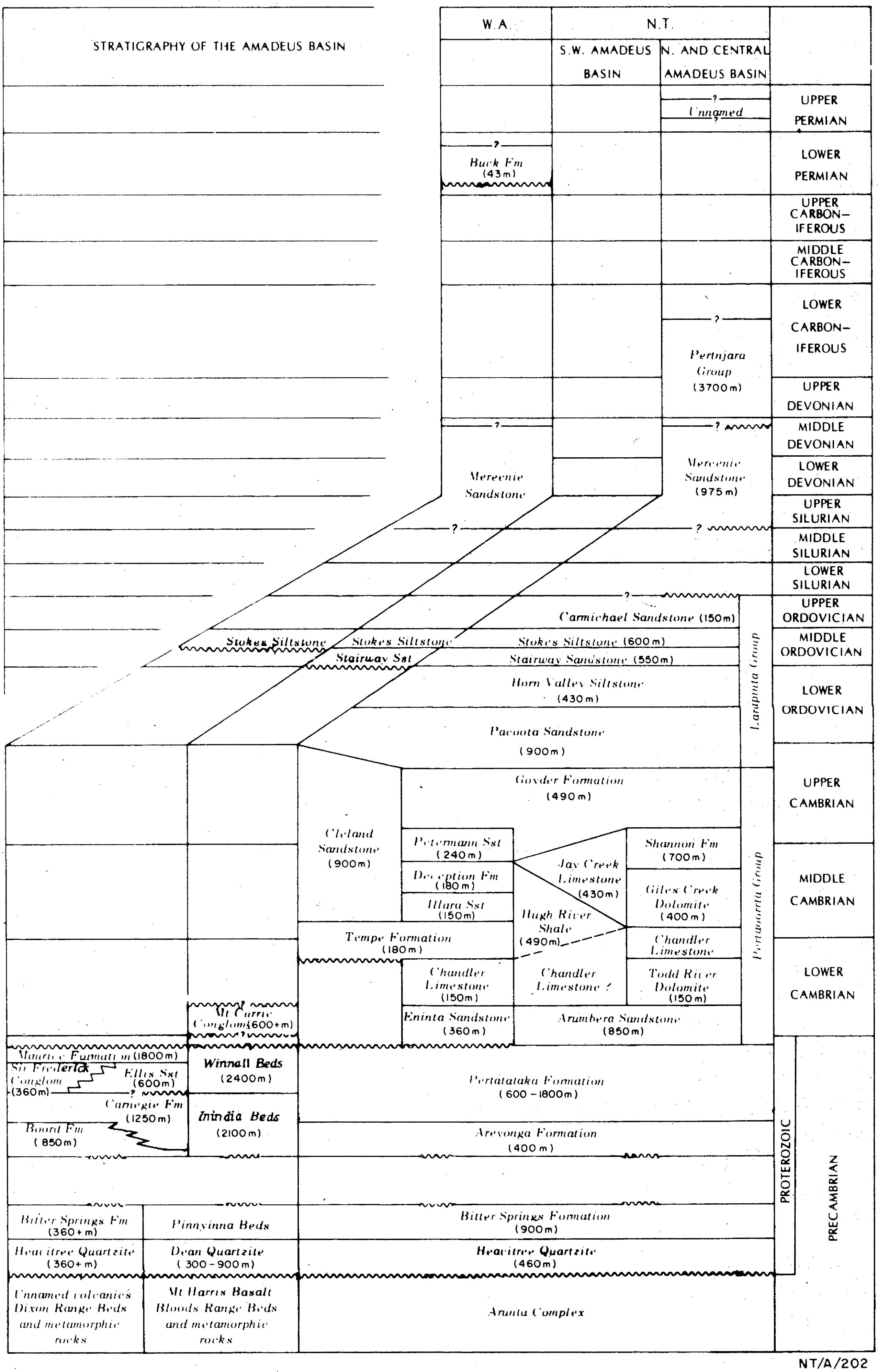

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Table 1

other, in the north-eastern part of the basin, lies locally in Cambrian evaporites.

4. HISTORY OF PETROLEUM EXPLORATION

Geological

The petroleum industry's search for petroleum in the Amadeus Basin has been assisted greatly by BMR field investigations and geological mapping on 1:250 000 scale (Table 2) which were carried out between 1949 and 1962. The reports of investigations of particular interest were those by Prichard and Quinlan (1962), Wells et al. (1965), and Ranford et al. (1965). The three reports covered respectively the Hermannsburg Sheet; the Mount Liebig and Mount Rennie Sheets; and the Lake Amadeus and Henbury Sheets.

In return, work by private industry geologists has assisted the BMR in map compilation and stratigraphic correlation. The most notable reports in this group are those by MacLeod, J.H., (1959); McNaughton, D.A., (1962); Leslie, R.B., (1960); Wulff, G.E., (1960), Stelck, C.R. and Hopkins, R.M., (1962) and Haites, T.B. (1963).

Magellan Petroleum (N.T.) Pty. Ltd. commissioned the consultant Dr D.A. McNaughton to carry out an evaluation of petroleum prospects in the Amadeus Basin. The reporting to Dr D.A. McNaughton of an alleged oil seep* 4 m long by 2 m wide about 4 km northwest of Hermannsburg Mission stimulated the search for petroleum by geological reconnaissance which assisted substantially in the locating of well sites on the Waterhouse, Mereenie, Gosses Bluff, Palm Valley, Carmichael, and Ooraminna anticlines.

Geophysical

Geophysical work commenced with the regional gravity surveys by Marshall and Narain in 1951. In 1957 the BMR extended this north-south line of control from Alice Springs to Giles, W.A. Further gravity control was added

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* A smaple of the seep material was tested in the BMR and found by J. Puchel to be more like refined product than crude oil.

Table 2. Summary of BMR Geological Mapping of the Amadeus Basin

Sheet Name	Sheet No.	Year Mapped	Comments
Alice Springs	SF 53-14	1964	Detailed reconnaissance.
Ayers Rock	SG 52- 8	1963	Reconnaissance and air-photo interp
Bloods Range	SG 52- 3	1962	Reconnaissance - some traverses.
Finke	SG 53- 6	1963	Detailed reconnaissance.
Hale River	SG 53- 3	1964	Detailed reconnaissance.
Henbury	SG 53- 1	1963	Detailed reconnaissance.
Hermannsburg	SG 53-13	1956,62,64	Detailed; area of type sections of Pacoota Sst, Horn Valley Slt, Stairway Sst and Stokes Slt.
Illogwa Creek	SF 53-15	1949,50,51,64	Detailed reconnaissance.
Kulgera	SG 53- 5	1963	Detailed reconnaissance.
Lake Amadeus	SG 52- 4	1962	Area of type section Carmichael Sandstone; det. rec.
Macdonald	SF 52-14	1962	Reconnaissance and air-photo interp
McDills	SG 53- 7	1964	General reconnaissance.
Mount Liebig	SF 52-16	1961	General reconnaissance.
Mount Rennie	SF 52-15	1961	General reconnaissance.
Petermann Ranges	SG 52- 7	1962,63	Reconnaissance and air-photo.
Rawlinson	SG 52- 2	1962	Mainly sketchy.
Rodinga	SG 53- 2	1964	Detailed reconnaissance.

by the BMR in 1959 and 1960 and an air magnetometer profile was flown from Alice Springs to Giles. A local gravity survey of Gosse's Bluff was run by From-Broken Hill Co. Pty Ltd. in 1958. In 1960 and 1961 further local surveys were carried out at Ooraminna structure, Alice Prospect and Mereenie anticline. In 1961 Magellan ran several long traverses, (1261 stations) along various tracks south and west of Alice Springs and results incorporated previous local work by Frome-Broken Hill. A major contribution came with the BMR helicopter survey in 1961-62 on a seven mile grid (See Langron, 1962, and Lonsdale and Flavelle, 1963).

The first recorded seismic work was carried out by the BMR in May-August 1961 (F.J. Moss- Amadeus Basin, Southern Margin, Seismic Survey, N.T. 1961, Record 1962/167). This was followed by the Palm Valley - Hermannsburg Seismic Survey, Amadeus Basin, N.T. 1962, (Record 1963/5). Namco Geophysical Co. carried out surveys over the Alice, Ooraminna and Mereenie Prospects for Exoil in 1962, and the BMR shot a cross-basin profile from the Gardiner Range through Gosse's Bluff into the MacDonnell Ranges, (Record No. 1964/66).

In 1964 Magellan shot additional seismic control lines around the northwestern half of Mereenie anticline.

The Missionary Plain Seismic and Gravity Survey in 1965 (Krieg & Campbell, 1965) led Magellan geoscientists to conclude that in the northern part of the Amadeus Basin there exist two arcuate Sub-basins separated by an ancestal ridge trending northeast through Gosse's Bluff to Tyler anticline and probably eastward to Glen Helen. Diapirism and imbricate thrusting in Precambrian, Cambrian and Ordovician sediments were shown by seismic profiles at Tyler and West Waterhouse and by gravity anomalies at West Waterhouse and West Carmichael-Deering Creek. The drilling prospects delineated by the survey were West Waterhouse, Tyler, Northeast Gardiner, and Carmichael anticlines.

The Central Amadeus Seismic Survey (Mandrel, 1974 & Krieg, 1974) was completed in May 1974. New recordings were carried out in:

(a) Mereenie - Glen Edith fold trend and NW Gardiner - Mt. Solitary thrust belt.

(b) Waterhouse - Ooraminna area.

and (c) Palm Valley area.

Generally, the new work improved the understanding of structure and stratigraphy but there are still serious problems in interpretation. Data quality was fair over synclinal areas but deteriorated to not reliable over the crests of anticlines where shallow formations outcrop and subsurface configuration is complex.

DRILLING

Twenty five petroleum exploration wells were drilled from February 1963 to October 1974 (Table 3). The locations of the wells are shown in Fig. 1. Most of the wells were located on closed anticlines delineated by surface geological mapping and deemed prospective by D.A. McNaughton (1962).

In 1963, an oil saturated core was taken in the Lower Stairway Sandstone in the BMR phosphate test hole AP 1. This find represents a genuine discovery of crude oil in the subsurface in the Amadeus Basin.

The Mereenie gas and oil field (Fig. 2) was discovered early in 1964 and was followed by the discovery of gas on the Palm Valley Anticline in 1965 (Fig. 3). Eight wells have been drilled on the Mereenie Anticline and three on the Palm Valley Anticline. The main producing formation in each anticline is the Cambrian to Ordovician Pacoota Sandstone, with smaller gas accumulations in the Ordovician Stairway Sandstone and the Ordovician Horn Valley Siltstone in the Palm Valley Anticline. At Mereenie the gas column is about 327 m (1073 ft) and the oil column has a minimum thickness of 97 m (318 ft). Condensate was produced at rates ranging from 5 to 14 barrels per million cubic feet ($28-78\ m^3/10^6 m^3$) of gas. Gas flow rates ranged from about 3 to 30 million cubic feet ($0{\cdot}08-0{\cdot}8 \times 10^6 m^3$) per day from the Pacoota Sandstone. Oil production rates from East Mereenie No. 4 (the first well to encounter free flowing oil) ranged from 160 to 350 barrels ($25-56\ m^3$) per day, depending on choke size. Acidization and fracturing in the well eliminated some of

Table 3. Summary of Petroleum Exploration Wells Drilled in the Amadeus Basin

Well Name (Operator)	Abbreviation (Fig. 1)	Locality (Plate 1)	Date Spud	Date T.D.	Total Depth m below RT	Total Depth ft below RT	Comments
raminna 1 (Exoil)	Oo1	16	2/63	6/63	1861.4	6107	First Amadeus Basin exploration well drilled; small flow of CH_4 from Areyonga Fm
ice 1 (Exoil)	A1	1	6/63	9/63	2291.5	7518	First liquid hydrocarbons found in basin in Middle Cambrian Jay Ck. Lst (non-commercial
reenie 1 (Exoil)	M1	12	12/63	2/64	1214.0	3983	Gas discovery in Stairway Sst (high pressure) and in Pacoota Sst
st Mereenie 1 (Exoil)	EM1	4	4/64	7/64	1436.5	4713	Confirmed the presence of gas in the Stairway and Pacoota Ssts.
st Mereenie 2 (Exoil)	EM2	5	9/64	11/64	1577.3	5175	Discovered oil column beneath gas zone in the Pacoota Sst; 1st air drilled well in Aus
st Mereenie 1 (Exoil)	WM1	23	11/64	1/65	1677.6	5504	Confirmed the presence of oil and gas; gas/ oil contact intersected.
. Charlotte 1 (Exoil)	MC1	13	12/64	2/65	2116.2	6943	Some gas shows in the Bitter Springs Fm.
lm Valley 1 (Magellan)	PV1	18	1/65	5/65	2029.4	6658	Gas discovery in Stairway Sst, and Horn Valley Siltstone
terhouse 1 (Centralia Oil)	W1	22	1/65	5/65	939.1	3081	Dry, abandoned.
sses Bluff 1 (Exoil)	GB1	8	2/65	3/65	1382.3	4535	Small gas flow from Stairway Sst.

Table 3. (cont.) Summary of Petroleum Exploration Wells Drilled in the Amadeus Basin

Well Name (Operator)	Abbreviation (Fig. 1)	Locality (Plate 1)	Date Spud	Date T.D.	Total Depth m below RT	Total Depth ft below RT	Comments
Johnny Creek 1 (Exoil)	JC1	11	2/65	3/65	267.3	877	Prematurely abandoned because of drilling difficulties
East Johnny's Creek 1 (Exoil)	EJC1	2	3/65	5/65	1933.7	6344	Petroliferous odours noticed while drillin the Horn Valley Sltst, Illara Sst, Tempe F
James Range 'A' 1 (Exoil)	JRA1	10	4/65	5/65	914.4	3000	Dry, abandoned. Traces of residual HCO's in Pertaoorrta Gp.
Highway Anticline 1 (Exoil)	HA1	9	5/65	6/65	1149.1	3770	No significant shows; angular unconformity at base of Pertaoorrta Gp.
Ochre Hill 1 (Exoil)	OH1	15	5/65	6/65	1146.4	3761	No significant shows; angular unconformity at base of Pertaoorrta Gp.
Erldunda 1 (Exoil)	E1	7	6/65	7/65	1665.1	5463	No significant shows; lower Ordovician hiatus, on lap of Carmichael Sst.
West Mereenie 2 (Exoil)	WM2	24	7/65	9/65	1523.1	4997	Gas mainly from Pacoota Sst; g/oil but not o/water contact determined.
East Mereenie 3 (Exoil)	EM3	5	11/65	1/66	1589.5	5215	Intersected Pacoota Sst within oil column, G/O and O/W contacts not determined.
Orange 1 (Magellan)	O1	17	9/66	10/66	2708.5	8886	Fresh water in Pacoota and Goyder indicatec considerable penetration along vertical fractures

Table 3. (cont.) Summary of Petroleum Exploration Wells Drilled in the Amadeus Basin

Well Name (Operator)	Abbreviation (Fig. 1)	Locality (Plate 1)	Date Spud	Date T.D.	Total Depth m below RT	Total Depth ft below RT	Comments
East Mereenie 4 (Exoil)	EM4	6	4/67	8/67	2667.0	8750	Gas in Stairway Sst and Pacoota Sst; completed as an oil producer from Pacoota Sst.
Tyler 1 (Magellan)	T1	21	6/68	6/69	3840.2	12,599	Deepest well drilled; no significant shows; lack of porosity.
Northwest Mereenie 1 (Exoil)	NWM1	14	7/69	8/69	1524.0	5000	No significant shows; deterioration in reservoir characteristics.
West Waterhouse 1 (Magellan)	WW1	25	8/69	10/69	1989.7	6528	No significant show; fracture porosity in Pacoota Sst.
Palm Valley 2 (Magellan)	PV2	19	12/69	2/70	1999.2	6559	Completed as a gas well; gas from Stairway Sst, Horn Valley Sltst and Pacoota Sst.
Palm Valley 3 (Magellan)	PV3	20	1/73	3/73	2408.2	7901	Significant gas flows only from Pacoota Sst; deterioration of reservoir charact.

Abbreviation	Name
A	Alice
EJC	East Johnny's Creek
EM	East Mereenie
E	Erldunda
GB	Gosses Bluff
HA	Highway Anticline
JRA	James Range 'A'
JC	Johnny Creek
M	Mereenie
MC	Mt. Charlotte
NWM	Northwest Mereenie
OH	Ochre Hill
Oo	Ooraminna
O	Orange
PV	Palm Valley
T	Tyler
W	Waterhouse
WM	West Mereenie
WW	West Waterhouse
BMR AP	Phosphate Test

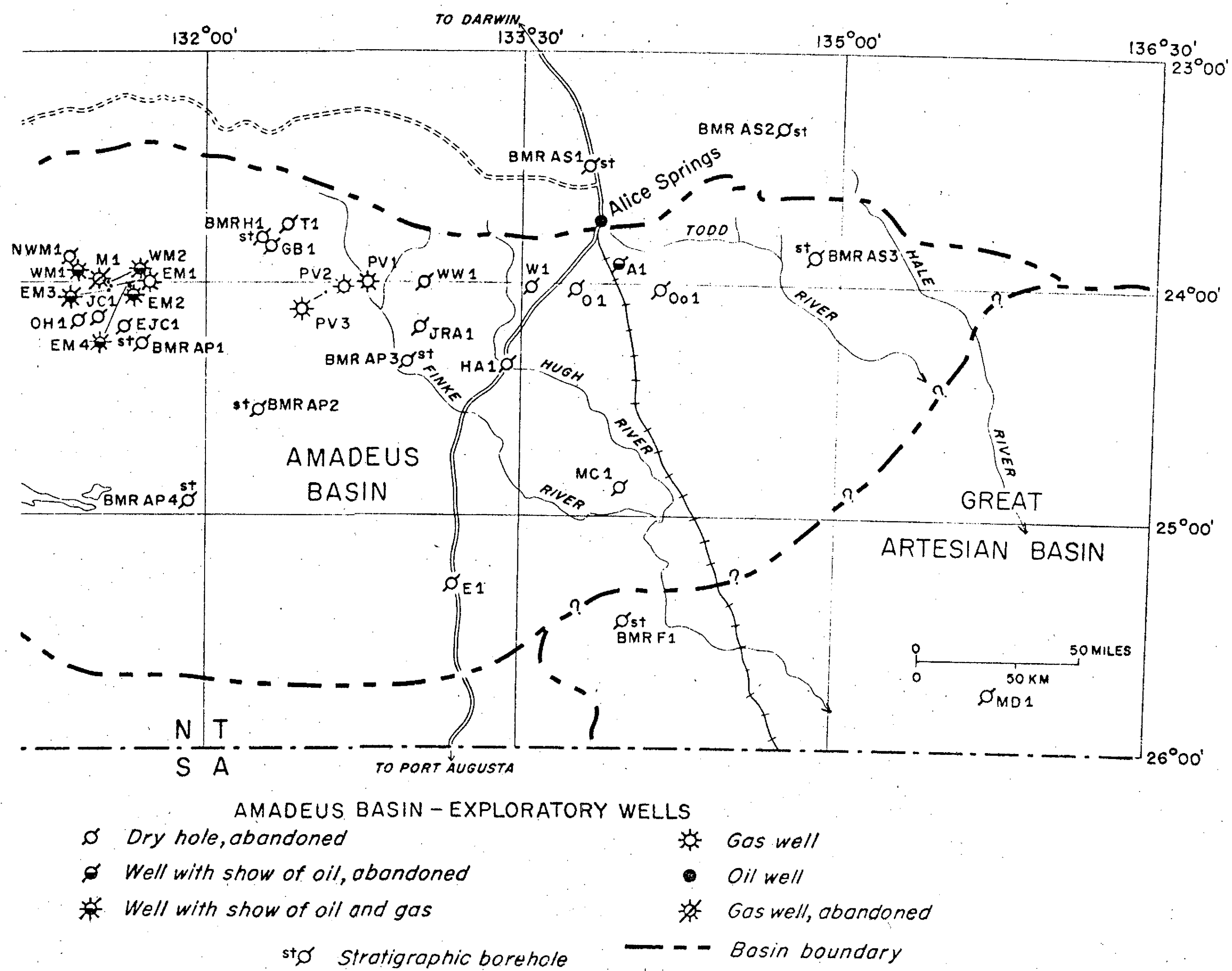
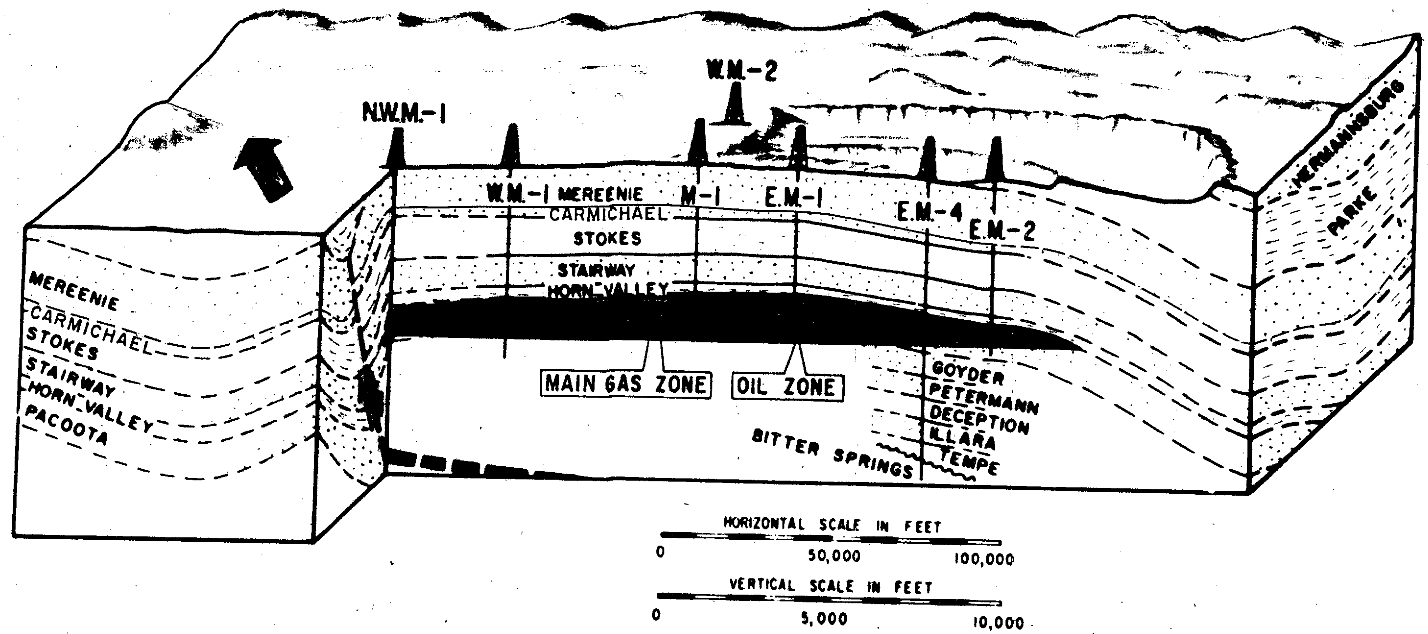


FIG. I

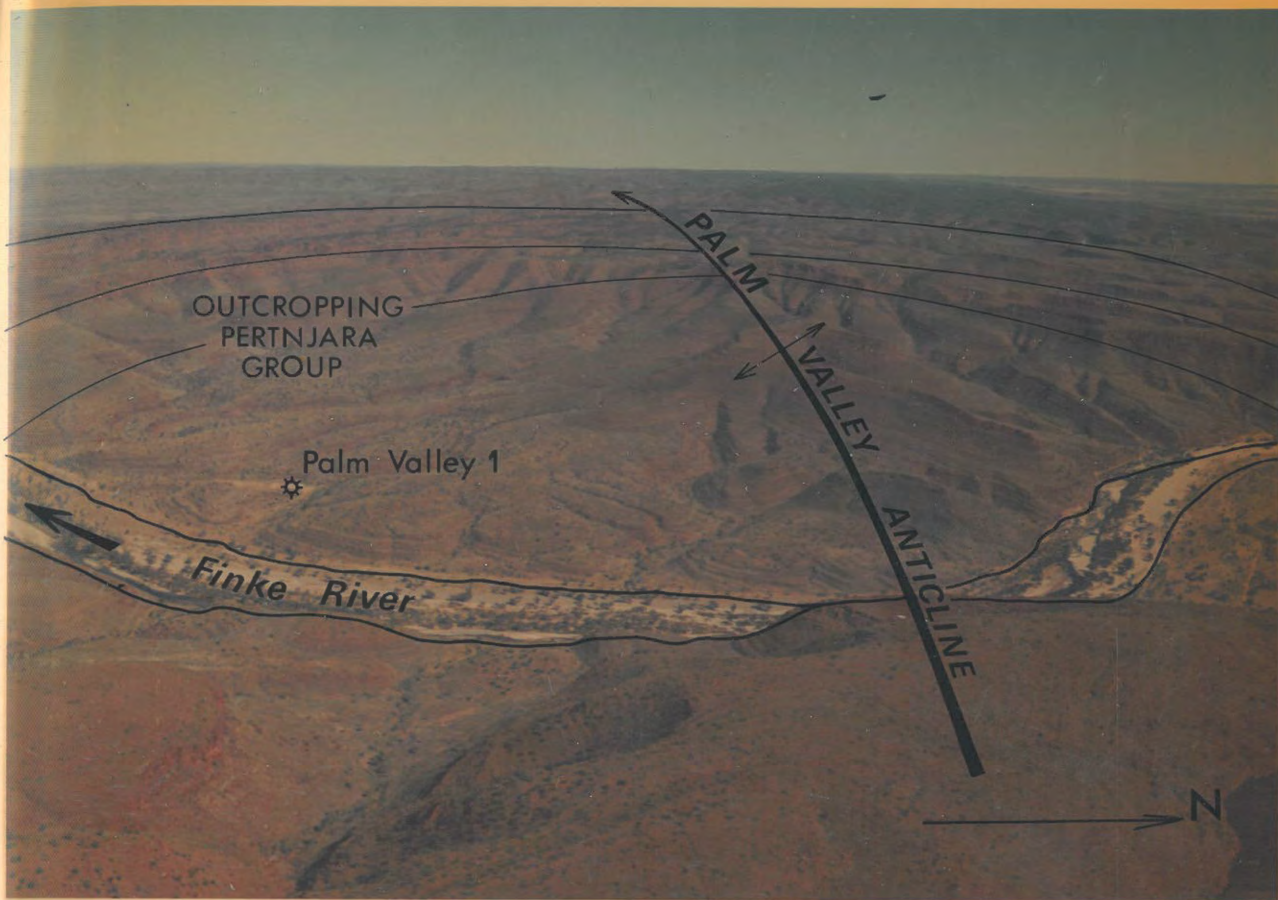
(after Wells et al. 1970)

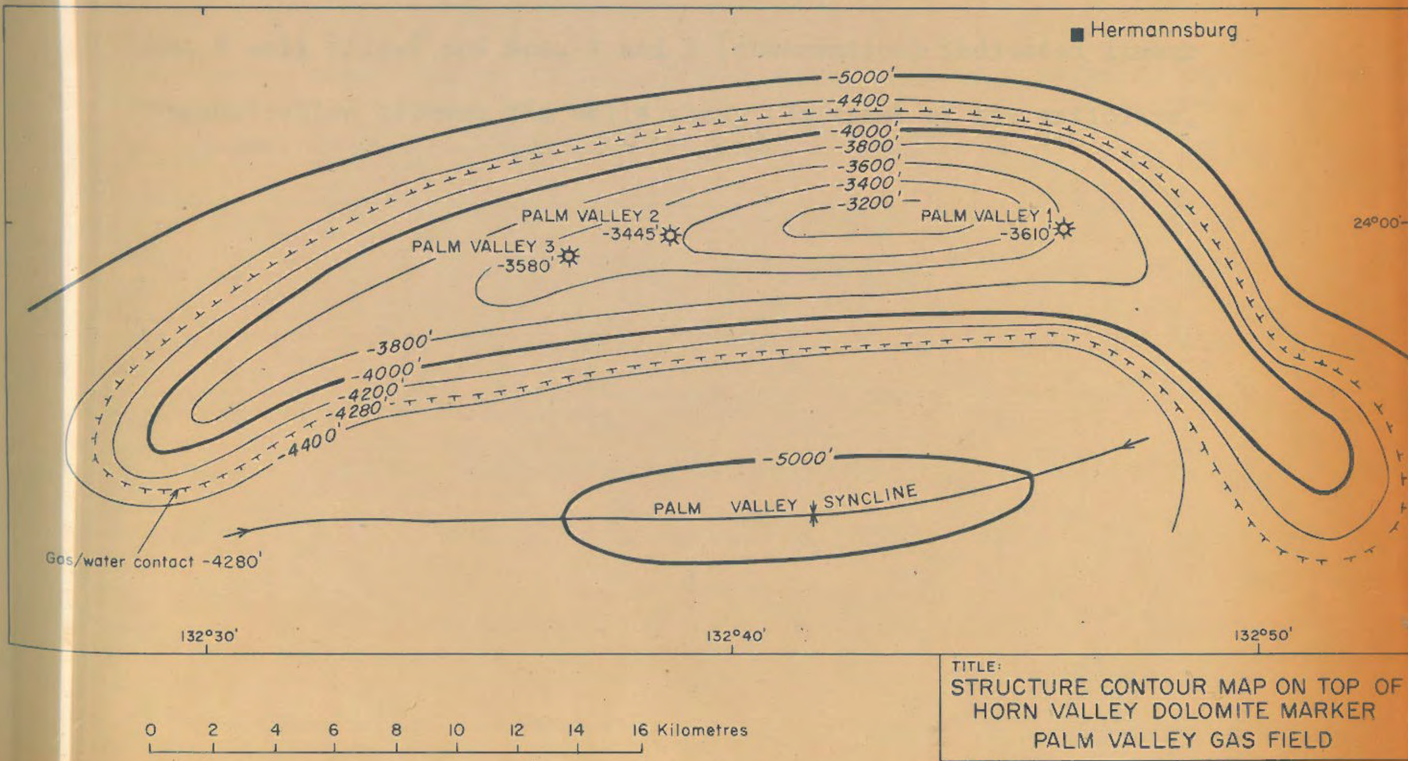


DIAGRAMMATIC BLOCK FIGURE SHOWING
THE GEOLOGIC SETTING OF THE MEREENIE FIELD

(modified after Magellan, 1968)

Fig. 2





TITLE: STRUCTURE CONTOUR MAP ON TOP OF HORN VALLEY DOLOMITE MARKER PALM VALLEY GAS FIELD			
AUTHOR: After Magellan		DATE: December 1974	
FILE Nº: NT/A/421	RECORD:	DRAWN BY: G.A.Young	Fig. 3

the formation damage caused by the drilling and completion techniques and demonstrated that the Pacoota reservoir responds favourably to conventional stimulation methods.

Gas occurs over an interval of about 305 m (1000 ft in Palm Valley No. 1 with production mainly from fractures in the lower Stairway Sandstone, Horn Valley Siltstone, and upper Pacoota Sandstone. Palm Valley No. 1 had a calculated open flow potential of 6.3 million cubic feet per day, but studies of build-up pressure data showed that its capacity would have been about ten times higher but for an extensive formation damage. Palm Valley No. 2 drilled with air to minimize well damage, tested 69.7 million cubic feet per day gas through a $2\frac{1}{4}$" orifice plate after penetrating only 0.6 m (2 ft) into the Pacoota reservoir.

Palm Valley No. 3 was completed in March 1973, as a shut-in gas producer, after a two-fold increase in the rate of flow (5MMCFD) was obtained by hydraulic fracturing of the Pacoota Sandstone Reservoir. Also an improvement of 365% in the calculated absolute open flow potential occurred in Palm Valley No. 1 (23 MMCF/D) after fracturing.

An interference study, between the three Palm Valley wells with No. 2 well (flow) and Nos. 1 and 3 (observation) indicated linear communication between the wells along the crest of the anticline.

5. PALINSPASTIC RECONSTRUCTION

Theory

Palinspastic reconstruction concerns the placement of rocks in their relative original positions (Kay, 1945). The sediments in many regions, including the Amadeus Basin, have been deformed by folding, faulting, and flow, gaining positions differing from those at their deposition. Geographic maps become successively less satisfactory base maps for older and older palaeogeographic distributions. Palinspastic maps are palaeogeographic base maps; they are essential to proper portrayal of palaeogeography.

Dennison (1968) outlined two common methods of restoring deformed strata:

(1) The sinuous bed method assumes that the original location of a point on a fairly competent folded stratum can be determined by measuring the length of that folded stratum in a structural cross-section extending from the stable continental interior or shelf, to the point in question and then replotting the straightened length of this sinuous line on a map.

(2) In 1961 Dennison introduced the procedure known as the equal-area method, suggested by Bucher (1955, p. 357). Bucher proposed that the area of a structural section measured down to the base of folding or to a décollement is constant before and after deformation thereby providing a basis for estimating the amount of orogenic foreshortening.

Before constructing a palinspastic map of the Amadeus Basin at the end of Larapinta Group deposition, the following assumptions were made:

(a) The original depositional edge of the Cambrian to Ordovician basin at the end of the Ordovician and the one least affected by subsequent deformation was near the present southern erosional margin of the basin.

(b) The main structures in the basin were formed by the Alice Springs Orogeny (Forman, 1965; Forman et al., 1966; Wells et al. 1967) during the Upper Devonian to Carboniferous time interval, and the axes of the folds generally trend between east-north-east and east-south-east. Other lineaments, trending in the southwesterly and southeasterly directions, are considered to be related to earlier fractures in the underlying basement. The style and pattern of folding have been largely controlled by décollement along evaporites in two and possibly three horizons (Bitter Springs Formation, Chandler Limestone, and Giles Creek Dolomite).

(c) The folding of the Larapinta Group occurred predominantly by horizontal forces from the north (Wells et al. 1962).

The cause and mechanism of deformation are outside the scope of this thesis, which is concerned, in part, with the amount, direction, and frame of reference of any position change resulting from orogenic disturbance.

Practice

Twenty nine well and 68 outcrop localities (total of 97) were plotted (Plate 1) on a structural base map which has present day geographic co-ordinates (after Wells et al. 1970, Plate 41). Table 4 lists the locality names and co-ordinates.

A structural analysis was made of the axial trends of major folds (over 50 km long). The trends and lengths of the various straight-line portion of the folds are shown in Tables 5 and 6, and are plotted on an azimuth frequency diagram (Fig. 4). The results show that the direction of maximum compression was 200° SSE, normal to the mean fold direction length.

A total of 6 published structural cross-sections of the Amadeus Basin were examined and the equal-area method of palinspastic restoration was performed (Figs. 5, 6 and 7). A grid overlay of the basin (Plate 2 & Fig. 8) was constructed parallel and normal to the calculated maximum

Table 4 - Locality Index

Locality Number	Well or Locality Name	1:250,000 Sheet Area	S-Latitude	E-Longitude
1	Alice 1	Alice Springs	23°54'47"	133°58'00"
2	East Johnny's Creek 1	Lake Amadeus	24°11'00"	131°37'55"
3	East Mereenie 1	Lake Amadeus	24°00'31"	131°33'51"
4	East Mereenie 2	Lake Amadeus	24°02'47"	131°38'50"
5	East Mereenie 3	Lake Amadeus	24°00'45"	131°33'10"
6	East Mereenie 4	Lake Amadeus	24°01'57"	131°37'48"
7	Erldunda 1	Kulgera	25°18'36"	133°11'48"
8	Gosses Bluff 1	Hermannsburg	23°49'15"	132°18'00"
9	Highway Anticline 1	Henbury	24°20'23"	133°27'06"
10	James Range 'A' 1	Henbury	24°10'42"	133°00'44"
11	Johnny Creek 1	Lake Amadeus	24°08'46"	131°29'41"
12	Mereenie 1	Mt. Liebig	23°59'10"	131°30'10"
13	Mt. Charlotte 1	Rodinga	24°52'03"	133°59'11"
14	Northwest Mereenie 1	Mt. Liebig	23°53'22"	131°22'27"
15	Ochre Hill 1	Lake Amadeus	24°07'58"	131°23'49"
16	Ooraminna 1	Rodinga	24°00'06"	134°09'50"
17	Orange 1	Rodinga	24°02'34"	133°46'32"
18	Palm Valley 1	Hermansburg, and Henbury	24°00'00"	132°46'20"
19	Palm Valley 2	Henbury	24°00'03"	132°38'47"
20	Palm Valley 3	Henbury	24°00'44"	132°37'00"
21	Tyler 1	Hermannsburg	23°45'23"	132°24'45"

Table 4 - Locality Index

Locality Number	Well or Locality Name	1:250,000 Sheet Area	S-Latitude	E-Longitude
22	Waterhouse 1	Rodinga	24°01'00"	133°32'00"
23	West Mereenie 1	Mt. Liebig	23°56'57"	131°24'44"
24	West Mereenie 2	Mt. Liebig	23°58'49"	131°32'22"
25	West Waterhouse 1	Hermansburg and Henbury	24°00'00"	133°06'30"
26	BMR AP1	Lake Amadeus	24°17'	131°41'
27	BMR AP2	Henbury	24°33'	132°15'
28	BMR AP3	Henbury	24°20'	132°58'
29	BMR AP4	Lake Amadeus	24°56'	131°55'
30	Sausage Hill SH	Mr. Rennie	23°42'	129°35'
31	Mt. Rennie MRW1	"	23°49'30"	130°25'
32	Johnstone Hill JH	"	23°38'30"	130°00'
33	Watson Range WR	Mt. Liebig	23°59'	131°03'
34	Cleland Hills MLW6	"	23°42'	130°40'
35	NW Glen Edith Hills GEN	"	23°41'	131°08'
36	East Overburned Section MLWS	"	23°44'	131°42'
37	West Gardiner Range MLW8	"	23°52'	131°45'
38	East Gardiner Range MLR7(b)	"	23°58'	131°55'
39	Carmichael Creek	"	23°41'30"	131°59'
40	East Idirriki Range MLR5	"	23°35'	131°48'
41	LAR3 (22 Km SE of Mt Murray)	Lake Amadeus	24°22'	130°40'
42	LAW1 (22 Km E of Mt Murray)	"	24°16'	130°45'
43	Kulpi Rock Hole LAC 12	"	24°18'	131°16'

Table 4 - Locality Index

Locality Number	Well or Locality Name	1:250,000 Sheet Area	S-Latitude	E-Longitude
44	Ochre Hill LAC 5	Lake Amadeus	24°04'30"	131°24'
45	Johnny Creek Q	"	24°08'	131°28'
46	Oval Syncline OS	"	24°33'	131°35'
47	George Gill Range LAC 1	"	24°13'	131°38'
48	Dead Horse Anticline LAR 1 & 2	"	24°21'	131°58'
49	Innindie 45	Ayers Rock	24°57'	131°59'
50	Kernot Range KW 8 & 10	Hermannsburg	25°09'30"	131°49'30"
51	Stokes Pass SP	"	23°34'	132°06'30"
52	Haast Bluff Road HBR	"	23°36'	132°19'
53	Goyder Pass Diapir GPD	"	23°39'	132°27'
54	Finke River FR	"	23°42'	132°40'
55	Ellery Creek EC	"	23°49'30"	133°04'
56	Farrer Spring 30	Henbury	24°23'	132°01'
57	Mt Levi 31	"	24°23'	132°09'
58	West Tempe Downs T	"	24°28'	132°12'
59	Walker Ck/Mt Shady	"	24°18'	132°14'
60	Petermann Ck 33		24°22'	132°17'
61	Angas Downs	"	24°54'30"	132°17'30"
62	Areyonga 2	"	24°10'	132°18'
63	Levi Range 87	"	24°34'	132°21'
64	East Areyonga K	"	24°07'	132°26'
65	Tempe Downs 34	"	24°24'	132°30'

Table 4 - Locality Index

Locality Number	Locality Name	1:250,000 Sheet Area	S- Latitude	E- Longitude
66	Deception Ck 35	Henbury	24°19'	132°33'
67	SW Seymour Ra. SS	"	24°43'	132°48'30"
68	West James Ra. L	"	24°10'	132°50'
69	Seymour Ra 42W	"	24°53'30"	132°55'
70	Palmer Ra HYC2	"	24°42'	132°55'
71	East James Ra	"	24°11'	132°56'
72	HYC1	"	24°11'30"	132°59'30"
73	Parkes Pass	"	24°19'	132°58'
74	East Seymour Ra ES	"	24°43'	133°02'
75	Mt Keartland V	"	24°11'	133°05'30"
76	Ippia Hills	"	24°59'	133°05'
77	Seymour Ra HYS1	"	24°51'30"	133°06'
78	Napple Bar	"	24°40'30"	133°06'
79	Nallesnum Hills	"	24°38'30"	133°12'
80	Palmer Valley	"	24°51'30"	133°14'
81	Waterhouse Ra HYR5	"	24°02'	133°21'
82	The Sisters HYR7	"	24°42'	133°22'
83	Mt. Sunday Ra KW1	Kulgera	25°00'	133°20'
84	Erlunda Ra KS1	"	25°04'	133°05'30"
85	Williams Bore ASA1	Alice Springs	23°41'	134°16'
86	Todd River ASR1	"	23°53'	134°18'30"
87	Ross River Chalet ASR2	"	23°33'	134°27'

Table 4 - Locality Index

Locality Number	Locality Name	1:250,000 Sheet Area	S Latitude	E Longitude
88	Ringwood ASR3	Alice Springs	23°50'	134°56'
89	Hugh R. RdR2/Rd C7	Rodinga	24°21'	133°36'
90	37 Km SW of Mt Charlotte Rd C1	"	24°50'	133°43'
91	Mt. Peachy Rd C8/RdR1	"	24°23'	133°52'
92	Mt. Charlotte Rd C4	"	24°43'	133°57'
93	Bokhara Rd C9	"	24°30'	133°57'30"
94	Mt. Charlotte Rd C3	"	24°41'	134°02'30"
95	Mt Rodinger Rd C6	"	24°37'	134°20'30"
96	Allambi Rd R7	"	24°13'	134°32'
97	Todd River Rd R3	"	24°14'30"	134°48'30"

compression direction. A planimeter was used to measure the cross-sectional area (A) and a pair of calipers were used to measure the stratigraphic thickness (h) in synclinal areas between the top of the Larapinta Group and top of the décollement surface. The folded position of eroded Larapinta Group sediments was estimated on several of the sections. Where the Larapinta Group was completely absent, the Pertaoorrta Group surface to décollement surface thickness in synclinal areas was measured, since the calculated amount of compression is similar for both Groups. On a regional scale, synclines appear to be passive features (Dennison, 1968, p. 195) and the orogenic deformation raises up anticlinal structures or perhaps produces faults.

Conclusions

Results of the calculated amounts of compression are shown in Table 7. The average amount of compression (expressed as a percentage of the calculated original length) was 12.4% (Sections KLM and NO are grouped together). This value is considerably less than the calculated compression for the Appalachian Mountains which ranges from 22% to 57% (Dennison, 1968, fig. 12-7). This difference can be attributed partly to the more competent nature of the Amadeus Basin sediments overlying the Bitter Springs Formation.

The intersection points of the grid with the structural cross-section were replotted after palinspastic reconstruction below the original cross-sectional lines (Figs. 5, 6 and 7). The new grid spacings were then used in the drawing up of the palinspastic base map (Plate 3 & Fig. 9) which provided a base for the isopach and lithofacies maps of the following chapter.

Table 5. Summary of Fold Lengths and Trends in the Amadeus Basin

Name of Anticline of Syncline (from North to South)	Length of Segment (km)	Direction of Segment (degrees)
Missionary Plain Syncline	30	106
" " "	75	85
" " "	20	116
" " "	42	73
Waterhouse Anticline	40	92
" "	12	66
Orange Creek Syncline	22	101
" " "	32	82
James Range Anticline - Gardiner Fault	35	106
" " " " "	23	137
" " " " "	40	106
" " " " "	23	76
" " " " "	22	100
Syncline between Mereenie Anticline and Gardiner Fault	45	103
" " " " "	50	130
" " " " "	60	115
" " " " "	110	93
Mereenie - Walker Creek Anticline	40	117
" " " "	22	132
" " " "	62	115
" " " "	42	119
" " " "	18	82

Table 5 Cont. Summary of Fold Lengths and Trends in the Amadeous Basin

Name of Anticline of Syncline (from North to South)	Length of Segment (km)	Direction of Segment (degrees)
Mereenie - Walker Creek Anticline	13	93
" " " "	70	98
" " " "	37	92
Deep Well - Hijinx Anticline	34	62
" " " "	11	135
" " " "	80	70
Syncline south of Mereenie Anticline	62	112
" " " "	15	sinuous
" " " "	65	120
" " " "	90	114
" " " "	43	101
Johnny Creek - Parana Hill Anticlines	23	134
" " " " "	42	121
" " " " "	37	109
" " " " "	64	101
Ochre Hill - Petermann Ck. Syncline	40	134
" " " " "	16	127
" " " " "	33	112
" " " " "	61	95
Watson Range Anticline	28	118
" " "	45	143
" " "	32	129

Table 5. cont. Summary of Fold Lengths and Trends in the Amadeus Basin

Name of Anticline of Syncline (from North to South)	Length of Segment (km)	Direction of Segment (degrees)
Syncline passing through Mt. Winter	60	129
" " " " "	40	141
Anticline passing through Cleland Hills	56	129
Syncline to the south of the anticline above	53	135
Major Anticline south of Mereenie Anticline	26	99
" " " " "	80	120
" " " " "	25	145
" " " " "	30	125
" " " " "	70	98
Bifurcating anticline joining the one above	23	59
" " " "	15	78
" " " "	25	55
" " " "	55	106
" " " "	65	130
" " " "	65	118
" " " "	60	101
Camel Flat Syncline	80	60
Syncline near Mt. Murray	18	136
" " "	30	121
" " "	30	114
Syncline south of Seymour Range Anticline	52	94

Table 5 cont. Summary of Fold Lengths and Trends in the Amadeus Basin

Name of Anticline or Syncline (from North to South)	Length of Segment (km)	Direction of Segment (degrees)
Synclines NE of Lake Neale	65	117
" " " "	40	122
" " " "	25	100
" " " "	50	113
" " " "	15	90
" " " "	25	103
" " " "	32	118
" " " "	62	110
Syncline south of Basedow Range	32	116
" " " "	22	85
Syncline north of Milton	51	107
Syncline south of Souths Range	40	90
" " " " "	42	102

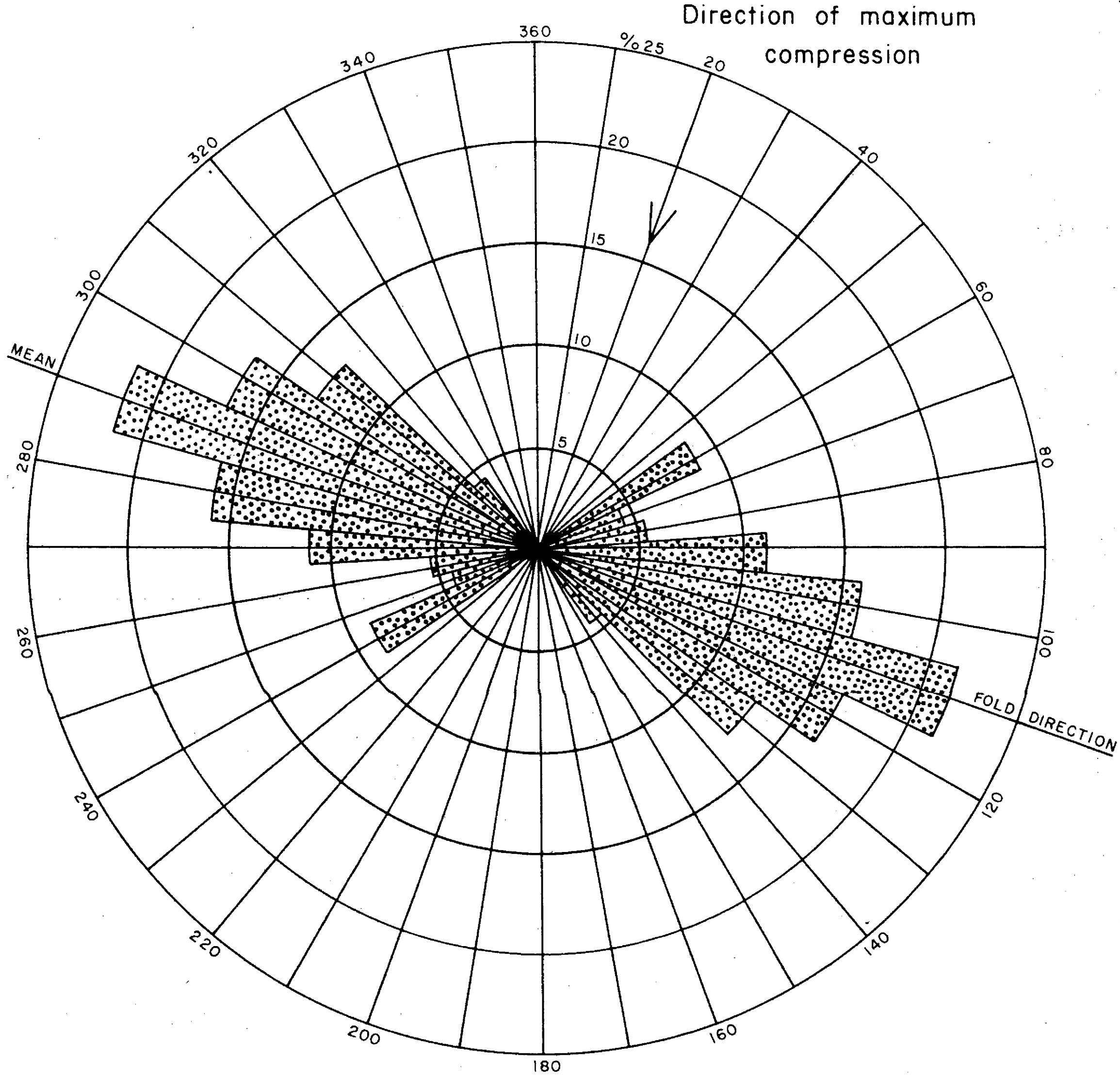
Table 6. Polar Frequency Plot Tabulation (See Fig. 4)

Class Limits (degrees)	Number of Fold Segments	Total Length of Segments (km)	% Length of Total
55 - 65	5	279	8.4
66 - 75	3	134	4.1
76 - 85	6	185	5.6
86 - 95	8	368	11.1
96 - 105	12	514	15.6
106 - 115	14	697	21.1
116 - 125	13	546	16.5
126 - 135	11	428	13.0
136 - 145	6	151	4.6
	Total 78	Total 3302	Total 100.0

Table 7. Results of Unfolding of The Amadeus Basin Sediments

(Equal Area Method)

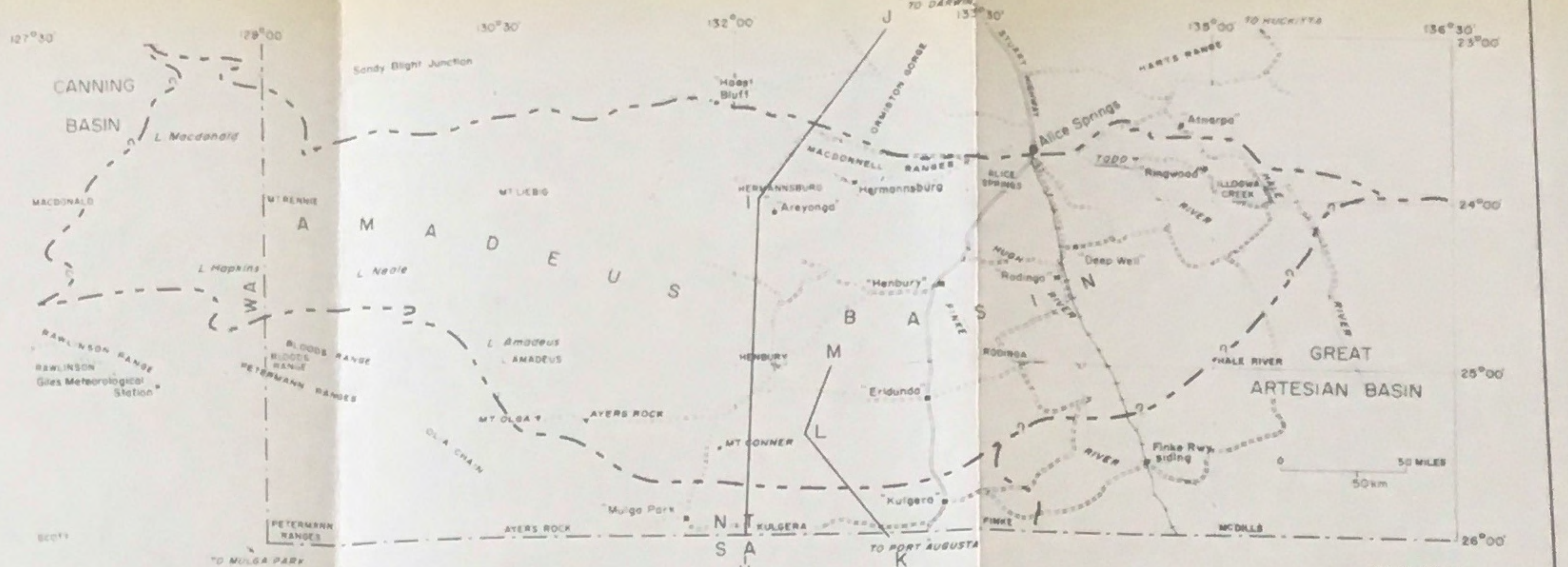
Structural Cross-Section	Compressed Length(km)	Original Length (km)	Amount of (km)	Compression % of original
AB (from Y-0 to Y-4)	104.8	115.2	10.4	9.0
CDEFG (Y-0 to Y-6)	165	184	19	10.3
HIJ (Y-0 to Y-7)	195	227.3	32.3	14.2
KLM (Y-0 to M)	47.1	59.5	12.4	21)) 11.5
NO (N to O including Y-3 to Y-6)	118.9	122.5	8.6	7)
PQRS (P to Y-10)	152	183.6	31.6	17.2
			Average	12.4



Polar frequency plot of fold lengths and directions in the Amadeus Basin

AUTHOR	DATE	Figure 4
L.E. Kurylowicz	24·10·74	


A
B
WOODROFFE THRUST
PETERMANN RANGES
PETERMANN RANGES NAPPE
BLOODS RANGE
LAKE NEALE
Track
Hull River
Larapinta Group
Y-0
Y-1
Y-3
Y-4
A-52·8
h-1·95
l-27·1
A-148·8
h-5
l-29·8
A-136·8
l-28·5
h-4·8
C
D
E
F
G
LAKE AMADEUS
JOHNNY CREEK ANTICLINE
MEREENIE ANTICLINE
OCHRE HILL ANTICLINE
CARMICHAEL STRUCTURE
DEERING FAULT
GARDINER RANGE ANTICLINE
BELT RANGE
Y-2
Y-5
Y-6
A-50·4
h-21·8
l-28
A-180
h-6
l-30
A-144
h-4·5
l-32
A-136·8
h-4·3
l-32
A-134·4
h-4·8
l-28
213·6
h-6·3
l-34
sed length 165 km
ginal length 184 km
CANNING BASIN
AMADEUS BASIN
GREAT ARTESIAN BASIN
Alice Springs
Hermannsburg
L. Macdonald
L. Hopkins
L. Amadeus
Ayers Rock
Finke
Kulgera
N.T.
S.A.
W.A.
NT/A/200
Highway
Track
Boundary of Amadeus Basin
State boundary
Y-0,Y-1,etc Palinspastic grid ordinates
A Cross-sectional area (km)(cross-hatched)
h Width of sediments in synclinal area(km)
l Calculated original length (km) between palinspatic grid points
V/H = 1
1:500,000
0 10 20 30 40 50 km
BUREAU OF MINERAL RESOURCES
CANBERRA ACT
AMADEUS BASIN
PALINSPASTIC READJUSTMENT
OF STRUCTURAL CROSS-SECTIONS
AB AND CDEFG
To accompany Record No
Author:- L.E. Kurylowicz after Wells et al 1970 Dec 1974
Fig 5



Highway

Track

Boundary of Amadeus Basin

State boundary

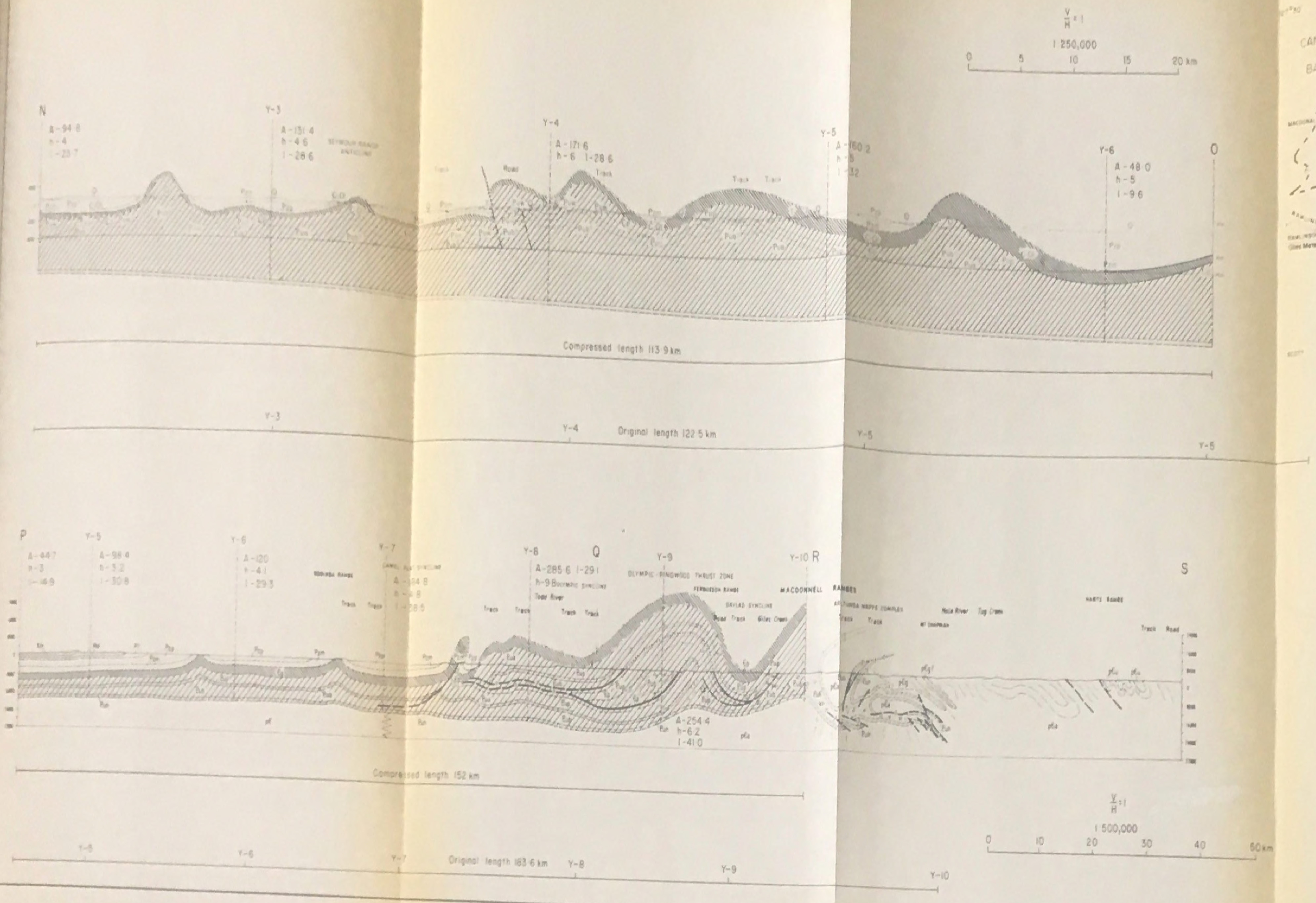
Y-0, Y-1, etc *Palinspastic grid ordinates*

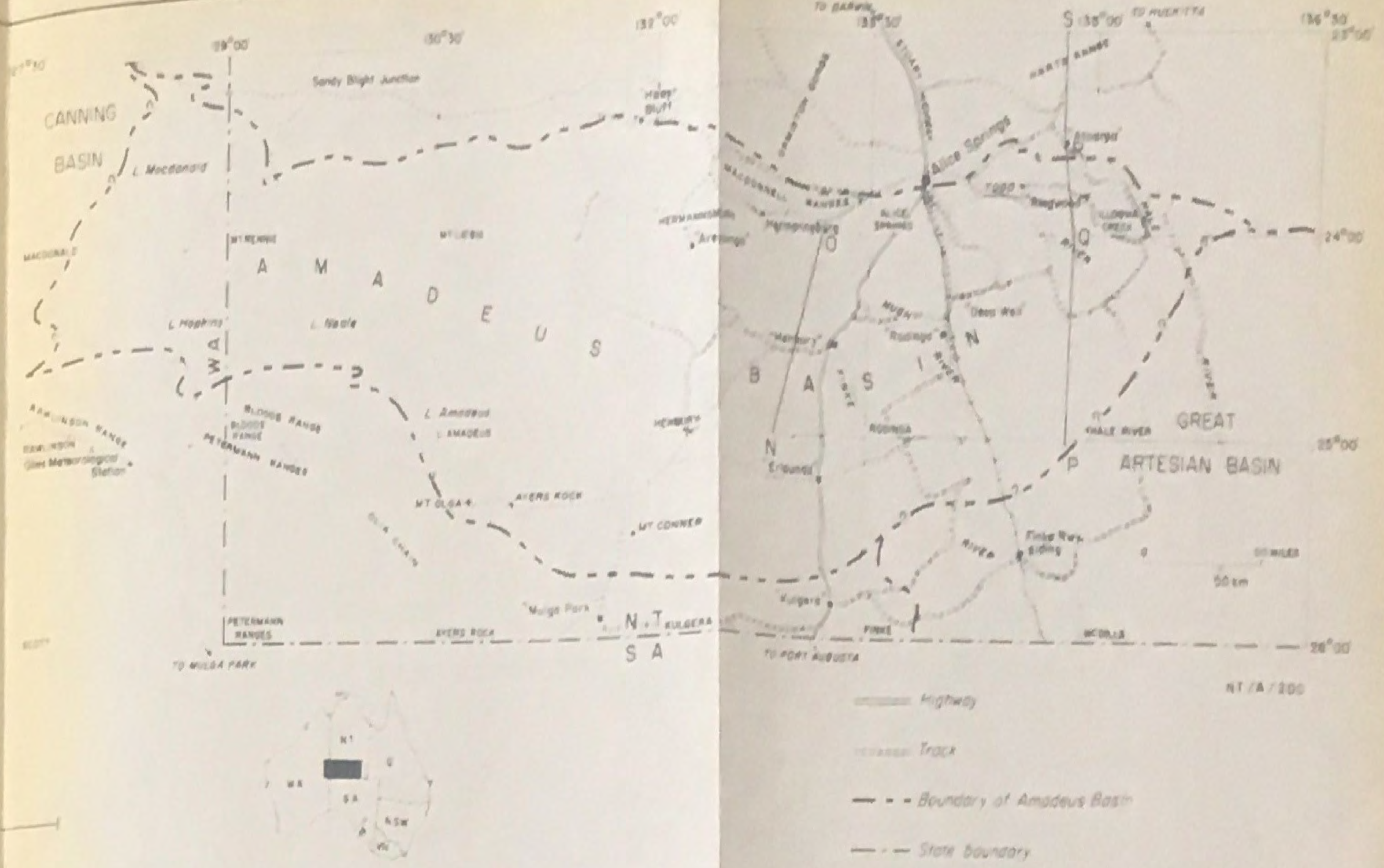
A *Cross-Sectional area (km^2)*

h *Width of sediments in synclinal areas (km)*

l *Calculated original length (km), between palinspastic grid points*

BUREAU OF MINERAL RESOURCES CANBERRA ACT		
AMADEUS BASIN PALINSPASTIC READJUSTMENT OF STRUCTURAL CROSS-SECTIONS HIJ AND MLK		
To accompany Record No	Author - L.E. Kurylowicz after Wells et al 1970 and Stewart A.J. 1967	Fig 6 Dec 1974





Highway

Track

Boundary of Amadeus Basin

State boundary

Y-4, Y-5, etc Palinspastic grid ordinates

A Cross-sectional area (km^2)

h Width of sediments in synclinal areas (km)

l Calculated original length (km), between palinspastic grid points

BUREAU OF MINERAL RESOURCES
CANBERRA ACT

AMADEUS BASIN
PALINSPASTIC READJUSTMENT
OF STRUCTURAL CROSS-SECTIONS
NO AND PQRS

To accompany Record 19	Author - L.E. Korsch... after Wells et al 1970 and Ranford et al 1965	Fig 7 Dec 1974


Direction of max compression
A —— B Structural cross-section line
Measured outcrop locality transposed
Well locality transposed
0 10 20 30 40 50 Miles
0 10 20 30 40 50 60 70 80 Kilometres
BUREAU OF MINERAL RESOURCES
CANBERRA, A.C.T.
AMADEUS BASIN
GRID FOR THE PALINSPASTIC RECONSTRUCTION
To accompany Record
Author L.E. Kurylowicz
Date Dec 974
Fig. 8


A — B Structural cross section line
Measured outcrop locality transposed
Well locality transposed
50 Miles
80 Kilometres
BUREAU OF MINERAL RESOURCES
CANBERRA, A.C.T.
AMADEUS BASIN
PALINSPASTIC BASE MAP
To accompany Record
Author L.E. Kurylowicz
Date Dec 1976
Fig 9

6. STRATIGRAPHY OF THE LARAPINTA GROUP

The author examined the wireline logs of twenty four wells which penetrated the Larapinta in the Amadeus Basin. Also core and cuttings, where available, were examined at the BMR Core and Cuttings Laboratory, Fyshwick. The resulting lithological correlations, based mainly on the gamma ray log, are shown in Plates 4,5,6 and in Table 8.

Stratigraphic information on the outcropping Larapinta Group was obtained from sources given in Table 9. The stratigraphic subdivisions as defined by Wells et al., (1970) were correlated throughout the basin. The thicknesses of the members of the Larapinta Group from 68 outcrop localities (Plate 1) are given in Table 10.

Haites T.B. (1963) used a statistical approach in determining the individual formation thicknesses, because of the poor exposure of some members of the Larapinta Group. His premise was that formations which form an uninterrupted sequence of deposition, their sections ought to be proportionally related, wherever the subsequent structural history left them intact. Therefore in well exposed sections, the thicknesses of an individual formation (e.g. Pacoota) should be a fixed percentage of the total thickness of the Larapinta Group.

However, the statistical approach used by Haites is no longer applicable because of the redefining of the Larapinta Group to include the Carmichael Sandstone. The depositional environment of the Carmichael Sandstone differs markedly from the other members of the Larapinta Group in that it is a deltaic deposit with a depocentre in the southern part of the basin. The percentage thickness of the members of the Larapinta Group is given in Table 11, only for comparison with Haites (1963) report.

TABLE8.

STRATIGRAPHIC CORRELATION OF THE LARAPINTA GROUP AMADEUS BASIN (SUBSURFACE)

in metres (feet)

Locality No	Well Name and No.	Rotary Table Elev. (sea level)	Carmichael Sandstone Fm Top BRT	Stokes Siltstone Fm Top BRT	Stairway Sandstone Fm Top BRT	Horn Valley Siltstone Fm Top BRT	Pacoota Sandstone Fm Top BRT
1	Alice 1	534.3 (1753)	Absent	Absent	Absent	Absent	644.7 (2115)
2	East Johnny's Creek 1	670.6 (2200)	Eroded	Eroded	Surface	48.8 (160)	105.8 (347)
3	East Mereenie 1	770.8 (2529)	330.4 (1084)	457.2 (1500)	769.6 (2525)	1005.8 (3300)	1082.0 (3550)
4	East Mereenie 2	718.4 (2357)	525.8 (1725)	633.4 (2078)	946.7 (3106)	1175.3 (3856)	1267.4 (4158)
5	East Mereenie 3	771.8 (2532)	670.6 (2200)	815.9 (2677)	1168.6 (3834)	1418.8 (4655)	1494.1 (4902)
6	East Mereenie 4	721.8 (2368)	461.8 (1515)	568.5 (1865)	881.2 (2891)	1129.6 (3706)	1211.6 (3975)
7	Erldunda 1	409.7 (1344)	274.3 (900)	Absent	Absent	Absent	Absent
8	Gosses Bluff 1	747.7 (2453)	Eroded	Surface	330.7 (1085)	Not penetrated	Not penetrated
9	Highway Anticline 1	492.6 (1616)	Eroded	Eroded	Eroded	Eroded	Eroded
10	James Range 'A' 1	487.7 (1600)	Eroded	Eroded	Eroded	Eroded	Eroded
11	Johnny Creek 1	673.9 (2211)	Eroded	Eroded	Eroded	Eroded	Surface
12	Mereenie 1	787.3 (2583)	320.0 (1050)	457.2 (1500)	783.3 (2570)	1036.3 (3400)	1127.8 (3700)

13	Mt Charlotte 1	384.0 (1260)	Absent	Absent	368.2 (1208)	Absent	Absent
14	Northwest Mereenie 1	732.1 (2402)	381.0 (1250)	541.0 (1775)	897.0 (2943)	1171.7 (3844)	1280.2 (4200)
15	Ochre Hill 1	701.0 (2300)	Eroded	Eroded	Eroded	Eroded	Eroded
16	Ooraminna 1	495.0 (1624)	Absent	Absent	Absent	Absent	Absent
17	Orange 1	590.7 (1938)	Absent	Absent	627.9 (2060)	735.5 (2413)	804.7 (2640)
18	Palm Valley 1	585.5 (1921)	891.5 (2925)	977.8 (3208)	1316.7 (4320)	1618.5 (5310)	1717.2 (5634)
19	Palm Valley 2	916.5 (3007)	1155.2 (3790)	1247.9 (4094)	1589.5 (5215)	1884.9 (6184)	1998.6 (6557)
20	Palm Valley 3	926.6 (3040)	1210.1 (3970)	1302.1 (4272)	1636.8 (5370)	1947.1 (6388)	2047.6 (6718)
21	Tyler 1	775.7 (2545)	2929.1 (9610)	3163.8 (10380)	3539.6 (11613)	Not penetrated	Not penetrated
22	Waterhouse 1	Not surveyed	Eroded	Eroded	Eroded	Eroded	Eroded
23	West Mereenie 1	756.5 (2482)	290.8 (954)	438.9 (1440)	791.9 (2598)	1051.6 (3450)	1151.5 (3778)
24	West Mereenie 2	772.7 (2535)	431.3 (1415)	593.1 (1946)	885.7 (2906)	1127.8 (3700)	1208.8 (3966)
25	West Waterhouse 1	674.8 (2214)	1257.0 (4124)	1328.3 (4358)	1489.6 (4887)	1715.1 (5627)	1790.1 (5873)
26	BMR AP 1	670.6 (2200)	Eroded	Surface	21.3 (70)	207.9 (682)	276.5 (907)
27	BMR AP 2	563.9 (1850)	Eroded	Eroded	Surface	160.6 (527)	Not penetrated
28	BMR AP 3	487.7 (1600)	Eroded	Eroded	Surface	231.3 (759)	Not penetrated
29	BMR AP 4	518.2 (1700)	Eroded	Surface	47.5 (156)	Absent	Absent

Table 9. Source of Stratigraphic Information

Locality No.	Source
1	Exoil (N.T.) Pty Ltd (1963) - WCR, subsidised.
2	McTaggart, N.R., & Benbow, D.D. (1965) - WCR.
3	Benbow, D.D., Lawson, W., and Panalp, R., (1964) - WCR.
4	" " " " " "
5	Benbow, D.D. (1966) - WCR.
6	Benbow, D.D., & Lawson, W. (1967) - WCR.
7	Pemberton, R.L. & McTaggart, N.R. (1965) - WCR, subsidised.
8	" , & Planalp, R.N., (1965) - WCR, subsidised.
9	McTaggart, N.R. & Pemberton, R.L., (1965) - WCR, subsidised.
10	" " " " " "
11	Benbow, D.D., & Planalp, R.N. (1965) - WCR.
12	Pemberton, R.L., Planalp, R.N., Chambers, S.S. & Webb, E.A. (1964) - WCR.
13	McTaggart, N.R., Pemberton, R.L. & Planalp, R.N., (1965) - WCR. subsidised.
14	Magee, R.A. (1970) - WCR.
15	McTaggart, N.R., & Benbow, D.D. (1965) - WCR.
16	Planalp, R.W. & Pemberton, R.L. (1963) - WCR, subsidised.
17	Magellan Petroleum (N.T.) Pty Ltd (1967) - WCR, subsidised.
18	" " " " " (1965) " "
19	Magee, R.A. (1971) - WCR.
20	Benbow, D.D., & Kerr, H.P. (1973) - WCR.
21	Huckaba, W.A. & Magee, R.A. (1969) - WCR.
22	Bullock & Associates (1965) - WCR.
23	Benbow, D.D., Lawson, W. & Planalp, R.W. (1965) - WCR.
24	" " " " (1965) - WCR.
25	Magee, R.A., & Pearce, L.G.G. (1970) WCR, subsidised.

<u>Note</u>: WCR - Well Completion Report

Table 9 cont. Source of Stratigraphic Information

Locality No.	Source
26	Barrie, J. (1964) - BMR Record 1964/195.
27	" " " " " " "
28	" " " " " " "
29	" " " " " " "
30	Haites, T.B. (1963)
31	Wells, A.T., Forman, D.J. & Ranford, L.C. (1965) - BMR Report 85, Section MRW 1.
32	Haites, T.B. (1963).
33	" " "
34	Wells, A.T., Forman, D.J., & Ranford, L.C. (1962) - BMR Record 1962/63 MLW 6.
35	Ibid.-MLR4. Table 2 and plates 7 & 13.
36	Ibid.-MLW2 & MLW 5. Table 2 and plate 11.
37	Haites, T.B. (1963) & Ibid.-MLW8 - Plate 12.
38	Wells, et al. (1962) - MLR7 (plate 10).
39	Haites, T.B. 1963
40	Macleod, J.H. (1959) - Plate 3A & Wells et al. (1962) - MLR 5. Plate 10.
41	Ranford, L.C., Cook, P.J. & Wells, A.T. (1965) - BMR Report 86, Plate 13.
42	Ibid. - LAW 1. Plate 13.
43	Ibid. - LAC 12. Plate 13.
44	Wells, A.T., Ranford, L.C. & Cook, P.J. (1963) - BMR Record 1963/51 - LAC 5. Plate 5.
45	Leslie, R.B. (1960) - Plate 36, No. 4 & Ranford et al (1965) - LAC 4.
46	Haites, T.B. (1963)
47	Ranford et al. (1965) - LAC 1.
48	Ibid. - LAR2 - Plate 11.
49	Leslie R.B., (1960) - Plate 3c No 32.
50	Wells, A.T., Stewart, A.J., & Skwarko, S.K. (1964) - BMR Record 1964/35 - KW 8 & 10, Plate 3.

Table 9 cont. Source of Stratigraphic Information

Locality No.	Source
51	Wells et al. (1962) - SP. Table 2.
52	Haites, T.B. (1963) - After Hopkins, R.M., Laing, C., & Stelck, C.R.
53	" " " After Gwinn, J.W. & Hopkins, R.M.
54	Wells et al. (1962) - FR Table 2 & McLeod, J.H. (1958) - Plate 3b.
55	Prichard, C.E., & Quinlan, T. (1962) - BMR Report 61 & Haites T.B. (1963).
56	Leslie, R.B. (1960) - Plate 3b, No 5.
57	Ibid.
58	Haites T.B. (1963) - After Hopkins, R.M., Laing, C. & Stelck, C.R.
59	" " " & Leslie, R.B. (1960) - Plate 3b, No 7.
60	Leslie R.B. (1960) - Plate 3b, No. 8.
61	" " " " " " "
62	Macleod, J.H. (1959) - Plate 3a.
63	Leslie, R.B. (1960) - Plate 3c No. 14.
64	Haites T.B. (1963) - After Hopkins R.M.
65	Leslie, R.B. (1960) - Plate 3b, No. 9.
66	" " " " " No. 11.
67	Haites, T.B. (1963) - After Hopkins R.M.
68	" " " " " " , Laing, C., & Stelck, C.R.
69	Leslie, R.B. (1960) - Plate 3d, No. 26.
70	" " " " " 24 & Ranford & Cook (1964) HYC2.
71	Haites, T.B. (1963) - After Hopkins, R.M. & Stelck, C.R.
72	Ranford, L.C. & Cook, P.J. (1964) - BMR Record 1964/40 - HYC1.
73	Haites, T.B. (1963) - After Hopkins, R.M., Laing, C., & Stelck, C.
74	" " " " " " " " " "
75	" " " " Gwinn, J.W.

Table 9 cont. Source of Stratigraphic Information

Locality No.	Source
76	Haites, T.B. (1963) - After Hopkins R.M.
77	Leslie, R.B. (1959) - Plate 3d, No. 28 & Ranford & Cook (1964) - HYS 1.
78	" " " " 3c, No. 16.
79	" " " " " " 19.
80	" " " " 3d, No. 29.
81	Ranford & Cook (1964) - HYR 5.
82	" " " - HYR 7.
83	Wells et al. (1964) - KW1. Plate 3.
84	" " " " - KS 1. Plate 3.
85	Wells, A.T., Ranford, L.C., Stewart, A.J., Cook, P.J. & Shaw, R.D. (1965) - BMR Record 1965/108 - ASA 1.
86	Ibid. - ASR 1.
87	" - ASR 2.
88	" - ASR 3.
89	" - Rd R2 / Rd C7.
90	" - Rd C1.
91	" - Rd C8 / Rd R1.
92	" - RdC4.
93	" - RdC9.
94	" - Rd C3.
95	" - Rd C6.
96	" - Rd R7.
97	" - Rd R3.

TABLE 10. THICKNESSES OF THE LARAPINTA GROUP - AMADEUS BASIN

metres (feet)

Locality No.	Carmichael Sst.		Stokes Slt.		Stairway Sst.		Horn Valley Slt		Pacoota Sst.		Total	
1	A		A		A		A		271.0	(889)	271.0+	(889+)
2	Er		Er		48.8+	(160+)	57.0	(187)	282.2	(926)	388.0+	(1273+)
3	126.8	(416)	312.4	(1025)	236.2	(775)	76.2	(250)	327.7	(1075)	1079.3	(3541)
4	107.6	(353)	313.3	(1028)	228.6	(750)	92.0	(302)	288.6	(947)	1030.2	(3380)
5	145.4	(477)	352.7	(1157)	250.2	(821)	75.3	(247)	95.4+	(313+)	919.0+	(3015+)
6	106.7	(350)	312.7	(1026)	248.5	(815)	82.0	(269)	298.4	(979)	1048.2	(3439)
7	103.6	(340)	A	A	A	A	A	A	A	A	103.6	(340)
8(including outcrop)	97.5	(320)	291.1	(955)	190.5	(625+)						
			Exaggerated thickness due to steep dips in well									
9	Er		Er		Er		Er		Er		Er	
10	Er		Er		Er		Er		Er		Er	
11	Er		Er		Er		Er		167.6+	(550+)	167.6+	(550+)
12	137.2	(450)	326.1	(1070)	253.0	(830)	91.4	(300)	86.3+	(283+)	894.0+	(2933+)
13	101.2	(332)	A	A	A	A	A		A		101.2	(332)
14	160.0	(525)	356.0	(1168)	274.6	(901)	108.5	(356)	243.8+	(800+)	1143.0+	(3750+)
15	Er		Er		Er		Er		Er		Er	
16	A		A		A		A		A		A	
17	A		A		107.6	(353)	69.2	(227)	378.0	(1240)	554.7+	(1820)+
18	92.4	(303)	335.9	(1102)	301.8	(990)	98.8	(324)	312.1+	(1024+)	1140.9+	(3743+)

A - Absent   Er - Eroded   NP - Not Penetrated

TABLE 10. THICKNESSES OF THE LARAPINTA GROUP - AMADEUS BASIN

19	92.7	(304)	341.7	(1121)	295.4	(969)	113.7	(373)		0.6+	(2+)	844.0+	(2769+)
20	92.0	(302)	334.7	(1098)	310.3	(1018)	100.6	(330)		360.6+	(1183+)	1198.2+	(3931+)
21 *	82.3	(270)	374.9	(1230)	299.9+	(984+)						758.6+	(2489+)
22	Er		Er		Er		Er			Er			
23	148.1	(486)	353.0	(1158)	259.7	(852)	100.0	(328)		312.4	(1025)	1173.2	(3849)
24	161.8	(531)	292.6	(960)	242.0	(794)	81.1	(266)		314.2+	(1031+)	1091.8+	(3582+)
25	71.3	(234)	161.2	(529)	225.6	(740)	75.0	(246)		199.6+	(655+)	732.7+	(2404+)
26	Er		21.3+	(70+)	186.5	(612)	68.6	(225)		3.4+	(11+)	279.8+	(918+)
27	Er		Er		160.6	(527+)	5.3	(17.5+)		NP		166.0+	(544.5+)
28	Er		Er		231.3+	(759)	4.0+	(13+)		NP		235.3+	(772+)
29	Er		47.6+	(156+)	51.8	(170)	A			A		99.4+	(326+)
30	?		67.0+	(220)+	44.2	(145)	33.3	(110)		67.1	(220)	211.8+	(695+)
31					35.1+	(115+)	71.0	(233)		56.4	(185)	162.5+	(533+)
32	?		51.8	(170)	30.5	(100)	24.4	(80)		54.9	(180)	161.6+	(530+)
33					76.2+	(250+)	106.7	(350)		182.9	(600)	365.8	(1200)
34			302.7	(993)	151.5	(497)	127.1	(417)		457.8	(1502)	1039.1+	(3409+)
35	?		341.4	(1120)	228.6	(750)	144.8	(475)	either	574.9+	(1886+)	574.9+	(1886+)
									or	286.5	(940)	1001.3+	(3285+)
36	?		275.8	(905)	150.3	(493)	151.8	(498)		427.3+	(1402+)	1005.2+	(3298+)
37	?30.5	?(100)	344.4	(1130)	276.5	(907)	186.8	(613)		480.4	(1576)	1318.6	(4326)

TABLE 10. THICKNESSES OF THE LARAPINTA GROUP - AMADEUS BASIN

38	54.9	(180)	461.2	(1513)	326.4	(1071)	161.2	(529)	647.4+	(2124+)	1651.1+	(5417+)
39					222.5+	(730+)	350.5	(1150)	350.5	(1150)	923.5+	(3030+)
40	?		335.3	(1100)	442.0	(1450)	426.7	(1400)	777.2	(2550)	1981.2+	(6500)
41					18.3+	(60+)	24.4	(80)	18.3	(60)	61.0+	(200+)
42	28.7	(94)	141.4	(464)	61.9	(203)	55.5	(182)	9.1+	(30+)	296.6+	(973+)
43					30.2+	(99+)	48.8	(160)	80.8	(265)	159.7+	(524+)
44	?		435.9	(1430)	286.5	(940)	140.2	(460)	76.2+	(250+)	938.8+	(3080+)
45	70.1	(230)	213.4	(700)	259.1	(850)	45.7	(150)	304.8	(1000)	893.1	(2930)
46			141.7	(465)	97.5	(320)	73.2	(240)	167.6	(550)	480.0+	(1575+)
47	65.2	(214)	22.6+	(74+)							87.8+	(288+)
48	78.9	(259)	258.8	(849)	179.2	(588)	60.4	(198)	320.6	(1052)	897.9	(2946)
49	A	A	A	A	30.5	(100)	A	A	A	A	30.5+	(100+)
50	14.9+	(49+)	123.4	(405)	76.5	(251)	A	A	A	A	214.8+	(705+)
51	?		609.6	(2000)	457.2	(1500)	426.7	(1400)	609.6	(2000)	2103.1+	(6900+)
52	?		304.8	(1000)	426.7	(1400)	320.0	(1050)	591.3	(1940)	1642.8+	(5390+)
53			554.7	(1820)	359.7	(1180)	448.1	(1470)	810.8	(2660)	2173.2+	(7130+)
54			335.3	(1100)	426.7	(1400)	304.8	(1000)	914.4	(3000)	1981.2+	(6500+)
55	79.2	(260)	?		327.7	(1075)	134.1	(440)	823.0	(2700)	1364.0+	(4475+)
56			432.8	(1420)	213.4	(700)	67.1	(220)	298.7	(980)	1012.0+	(3320+)
57	?		301.8	(990)	185.9	(610)	30.5	(100)	310.9	(1020)	829.1+	(2720+)
58	?		421.2	(1382)	254.5	(835)	59.4	(195)	256.3	(841)	991.5+	(3253+)

TABLE 10. THICKNESSES OF THE LARAPINTA GROUP - AMADEUS BASIN

59	106.4	(349)	253.0	(830)	228.6	(750)	45.7	(150)	333.8	(1095)	967.4	(3174)
60			277.4	(910)	176.8	(580)	30.5	(100)	365.8	(1200)	850.4+	(2790+)
61					91.4+	(300+)	A	A	A	A	91.4+	(300+)
62	?		460.2	(1510)	213.4	(700)	143.3	(470)	563.9	(1850)	1380.8+	(4530+)
63	?		274.3	(900)	137.2	(450)	76.2	(250)	301.8	(990)	789.4+	(2590+)
64	?		243.8	(800)	243.8	(800)	91.4	(300)	381.0	(1250)	960.1+	(3150)
65	?		295.7	(970)	231.6	(760)	94.5	(310)	280.4+	(920+)	902.2+	(2960+)
66	?		243.8	(800)	121.9	(400)	76.2	(250)	390.1	(1280)	832.1+	(2730+)
67	?		213.4	(700)	76.2	(250)	125.0	(410)	A	A	414.6+	(1360+)
68	?		403.3	(1323)	171.0	(561)	105.8	(347)	320.3	(1051)	1000.4+	(3282+)
69	?		182.9	(600)	143.3	(470)	48.8	(160)	A	A	374.9+	(1230+)
70	62.2	(204)	158.5	(520)	125.0	(410)	41.1	(135)	A	A	386.8	(1269)
71	?		324.0	(1063)	153.0	(502)	67.7	(222)	486.8	(1597)	1031.4+	(3384+)
72	?		279.8	(918)	268.2	(880)	74.1	(243)	625.8	(2053)	1247.9+	(4094+)
73	?		130.5	(428)	298.7	(980)	128.0	(420)	259.7	(852)	816.9+	(2680+)
74	?		185.9	(610)	91.4	(300)	42.7	(140)	A	A	376.7+	(1050+)
75	?		396.3	(1300)	198.1	(650)	85.3	(280)	594.4	(1950)	739.1+	(2425+)
76			21.3+	(70+)	106.7	(350)	A	A	A	A	128.0+	(420+)
77	?		152.4	(500)	121.9	(400)	A	A	A	A	274.3+	(900+)
78	?		243.8	(800)	109.7	(360)	41.1	(135)	A	A	394.6+	(1295+)
79	?		228.6	(750)	129.6	(425)	13.7	(45)	21.3	(70)	392.2+	(1290+)

TABLE 10. THICKNESSES OF THE LARAPINTA GROUP - AMADEUS BASIN

80	?		41.1	(135)	97.5	(320)	36.6	(120)	A	A	175.2+	(575+)
81							25.3+	(83+)	448.7	(1472)	474.0+	(1555+)
82					96.3+	(316+)	23.8	(78)	19.8	(65)	139.9+	(459+)
83	103.3	(339)	14.6	(48)	105.2	(345)	A	A	A	A	223.1	(732)
84	21.3+	(70+)	26.8	(88)	67.7	(222)	A	A	A	A	115.8+	(380+)
85	Er	Er							771.1+	(2530+)	771.1+	(2530+)
86	"	"							123.4+	(405+)	123.4+	(405+)
87	"	"							123.4+	(405+)	123.4+	(405+)
88	"	"							present			
89	?		138.7	(456)	179.8	(590)	44.2	(145)	303.3	(995)	666.0+	(2185+)
90	Er	Er	18.3+	(60+)	108.2	(355)	A	A	A	A	126.5+	(415+)
91	"	"			108.2	(355)	36.5	(120)	309.5	(1015)	454.2+	(1490+)
92	"	"	32.0+	(105+)	102.1	(335)	A	A	A	A	134.1+	(440+)
93	"	"			125.0	(410)	27.4	(90)	105.2	(345)	237.6+	(845+)
94	"	"			93.0	(305)	A	A	A	A	93.0+	(305+)
95	"	"			68.6	(225)	A	A	A	A	68.6+	(225+)
96	A	A	A	A	A	A	A	A	A	A	A	A
97	A	A	A	A	A	A	A	A	A	A	A	A

TABLE 11. FORMATION THICKNESSES EXPRESSED AS

% OF TOTAL LARAPINTA GROUP THICKNESS

Locality No.	Carmichael	Stokes	Stairway	Horn Valley	Pacoota	Total 100%
3	12	29	22	7	30	100
4	10.5	30.5	22	9	28	"
6	10	30	24	8	28	"
23	12.5	30	22	9	26.5	"
20	7.5	28	26	8	30.5	"
37	4	25.5	20.5	14	36	"
38	3.5	28	19.5	10	39	"
40	4.5	16	21.5	20.5	37.5	"
42	8	38.5	17	15	21.5	"
45	7	24	29.5	5	34.5	"
51	5	27.5	20.5	19.5	27.5	"
71	4.5	30	14	6.5	45	"
75	2.5	30.5	15	6.5	45.5	"
Average	7.0	28.5	21	10.5	33	100
or	1:4					

Carmichael : Stokes Slt
Sst thickness   thickness

Definition

Tate (1896) first used the name Larapintine Series in the report on the Horn Expedition of 1892. Madigan (1932) used the same name and placed his No. 4 Quartzite (Pacoota Sandstone) at the base of the series. Chewings (1935) subsequently revised the name to Larapinta Series, and Prichard & Quinlan (1962) renamed it the Larapinta Group.

Wells et al. (1970) redefined the Larapinta Group to include five formations, which in ascending order are: Pacoota Sandstone, Horn Valley Siltstone, Stairway Sandstone, Stokes Siltstone, and Carmichael Sandstone (Table 1). The group, which ranges in age from Upper Cambrian to Upper Ordovician, conformably overlies the Pertaoorrta Group in places. Elsewhere it unconformably overlies Pertaoorrta Group and Proterozoic sediments. It is unconformably overlain by the Mereenie Sandstone in the east whereas in the west the contact is apparently conformable.

When Prichard and Quinlan (1962) defined the Larapinta Group, they included a silty red-brown sandstone (now known as the Carmichael Sandstone) at the top of the Stokes Formation. Wells et al. (1964, 1965) and Ranford et al. (1965) mapped the same sandstone as the lower part of the Mereenie Sandstone. Their upper part of the Mereenie Sandstone corresponds to the original Mereenie Sandstone as defined by Prichard and Quinlan (1962).

Pacoota Sandstone

Definition

Prichard and Quinlan (1962, p. 19) defined the Pacoota Sandstone as "a series of silicified quartz sandstones conformably overlying the Goyder Formation of the Pertaoorrta Group and succeeded conformably by the Horn Valley Formation."

Type Locality

Ellery Creek (locality 55).

Outcrop Lithology

At Ellery Creek (loc. 55), the base of the Pacoota Sandstone is placed at the change of lithology from a dominantly soft and calcareous, very fine-grained quartz sandstone of the Goyder Formation to a fine and medium-grained quartz sandstone, mostly cemented by silica (Prichard & Quinlan, 1962 p. 19). The silicified quartz sandstone forms the bulk of the formation; some beds of silty quartzose sandstone are also present. Much of the Pacoota Sandstone is crossbedded and ripple marked, and suncracks are preserved.

A bed of 'pipe rock' (about 36 m thick) occurs about 120 m above the base. It is lithologically similar to the rest of the formation, but is packed with worm tubes (Scolithus) normal to the bedding planes. Most tubes are about 1.6 mm in diameter and 20 to 30 cm long, although the largest are 3.2 mm in diameter and 60 cm long. They are usually closely spaced - up to eight per square centimetre. The 'pipe rock' in single beds (up to 6 m thick) reoccurs upwards throughout the Pacoota Sandstone.

The top of the formation is placed at the top of a bed of hard quartzose sandstone, which is succeeded by the soft dark siltstone with thin lenses of quartz sandstone at the base of the Horn Valley Formation.

Intraformational breccias are recorded at Finke River and Glen Helen (loc. 54) where a breccia zone 9 m thick occurs 59 m above the base of the Pacoota Sandstone. In the Levi Range (near loc. 63) pebbles of chert and silicified sandstone up to 2.5 cm in diameter are common. Along the northeastern eroded margin of the basin, pebbles up to 5 cm in diameter and in the northwestern part of the basin pebbles up to 10 cm in diameter are present in the Pacoota Sandstone. The similarity in stratigraphic position of the breccia and/or conglomerate indicates that it was probably formed by slumping as suggested by Prichard & Quinlan (1962).

In the northwestern part of the basin, the Pacoota Sandstone conformably overlies the Cleland Sandstone (Wells et al. 1965 p24). In several places on the Mt Rennie 1:250 000 sheet area, the contact with the Cleland Sandstone is marked by a thin bed of pisolitic ironstone, and the Pacoota Sandstone is ferruginized and red-brown in colour.

In the northern part of the basin, (e.g. Idirriki Range, and loc. 36 & 40), a prominent bed, extremely rich in glauconite, has been observed in the Pacoota Sandstone. It occurs mainly in the upper half of the formation.

In the central and northeastern parts of the basin, there is a high proportion of kaolinitic matrix in the sandstone.

A few pelletal phosphatic sandstones which occur in the Pacoota Sandstone were observed in the Waterhouse Range (loc. 81) and at Mt Shady (loc. 59). These pellet bands are probably of very limited extent and form a minor proportion of the Pacoota Sandstone sequence (Ranford et al. 1965).

In the northeastern part of the basin current directions in the upper part of the Pacoota Sandstone in the Williams Bore area (near loc. 87) suggest that the main currents were from the southwest (Wells et al. 1967).

The N'Dahla Member of the Pacoota Sandstone was defined (Wells et al. 1967 p 45) as a thin sequence of clayey and pebbly sandstone, with minor beds of conglomerate and thin beds of limestone. The member is confined to the northern limb of the Ross River Syncline. At N'Dahla Gorge, the 15 m thick N'Dahla Member is unconformably overlain by the Mereenie Sandstone.

It consists of dark red-brown to purple-brown medium to coarse-grained, glauconitic, poorly sorted, friable, clayey sandstone. Pebbles are present, and also a few beds of conglomerate composed of fragments of siltstone and limestone in a coarse glauconitic sandstone matrix. Some thin beds of limestone are also present.

Subsurface Lithology

The formation can be subdivided into four broad lithological units (after Huckaba, 1970) which in ascending order are numbered P4 to P1 (Plates 4, 5, and 6). P4 is referred to also as the 'Lower Pacoota'. It consists of over 113 m of red, pink, and green sandstones with minor irregular interbeds of red, green, and grey shales. The sandstones are quartzose and mineralogically mature. They are texturally immature being mostly fine to medium-grained, and mostly poorly to moderately well sorted. The upper 10 m of the 'Lower Pacoota' are highly resistive (electric log). The zone is characterized by an increase in grain size and presence of some carbonate cement.

P3 unit overlying the 'Lower Pacoota' is up to 107 m thick. It contains two clean sandstones between 4 m and 8 m thick which are generally light brown in colour and coarser-grained than the intervening pink beds. The intervening beds themselves are mostly sandstone but contain numerous interbeds of red, green, dark grey shales and siltstones. Cross-bedding is visible in cores and there is some evidence of quartz pebble horizon, which may be a stratigraphic equivalent of the breccia zones in outcrop. There is an apparent lack of worm burrows in the pink parts of the P3 unit.

The base of the next unit P2 is marked by distinctive gamma ray high, richly glauconitic, fine to medium-grained silty sandstones about 25 m thick. They are most probably correlatives of the prominent glauconitic bed in the Idirriki Range and Gardiner Range. The sandstones are calcareous and contain common lithic fragments of black shale. Dark grey to occasionally red shale interbeds are common and the interspersed shale content of the sandstones is also high (gamma ray). One prominent cleaner sandstone up to 8 m thick occurs in the middle of a 70 m unit.

Unit P1 is the most variable part of the Pacoota Sandstone as far as thickness is concerned; it ranges from 37.5 m to 107.9 m. There are five major sandstones in a section consisting of organically churned sands and shales, with the shale content increasing upwards. Numerous worm burrows, commonly normal to the bedding are present. The shales are generally dark grey to black, and pyritic, while red and green shales are fairly rare. The sandstones are commonly fine to very fine-grained and in places grade to siltstone. They contain traces of pyrite, occasional glauconite, dark grey lithic fragments, and shell fragments. The cleaner sandstones are either fine or fine to medium-grained, and may be well sorted. The well sorted grains are commonly angular due to the development of quartz overgrowths. The five major sandstones decrease in thickness towards the top (from about 17 m to 5 m). At places, the top of the Pacoota Sandstone is a richly glauconitic, fine grained, calcareous, silty sandstone containing some shell fragments and interbeds of brown siltstone.

The contact with the overlying black, fossiliferous shales and siltstones of the Horn Valley Siltstone is of the base of the limestone and dolomite beds marked by the low gamma ray and a high resistivity reading.

Subsurface correlation was carried out by means of gamma ray log, and resistivity logs together with reference to core and cutting descriptions. East Mereenie No. 4 (loc. 6) was used as a reference well because it penetrated complete development of the Larapinta Group. The thicknesses of the individual Pacoota Sandstone units in the subsurface are given in Table 12.

Age

The Pacoota Sandstone ranges from the late Upper Cambrian (Trempealeauian)to Lower Ordovician (Arenigian) in age (Joyce G. Tomlinson in Wells et al. 1970). Most of the sandstone is apparently barren of fossils, but some bands, particularly in the Ross River area (loc. 85), are rich in trilobites, brachiopods, pelecypods, gastropods, ribeirioids, nautiloids, and numerous trace fossils. The vertical worm? Scolithus, forms pipe-rock, which is a common feature of the Pacoota Sandstone.

Petrography

In general, the arenites of the Pacoota Sandstone are mineralogically mature (quartzose), and texturally both supermature (originally well rounded and well sorted) and, in places, immature (over 5% clay) in the sub-greywacke specimens (Appendix I). The modal grain size ranges from very fine to coarse sand. Most of the arenites may be classified as quartzose arenite (classification after Crook, 1960), having equal portions of non-undulating and undulatory quartz. In places the arenites grade into feldspathic sub-labile arenites (subarkose and subgreywacke).

The basal unit, P4, a quartzose arenite, is bimodal in places. The overlying unit, P3, is predominantly a feldspathic sub-labile arenite (subarkose). Alunite, $KA1_3(OH)_6\ (SO4)_2$ replaces quartz in core 19 in Palm Valley No. 1 (thin section at 6348 ft BRT). Glauconite and calcite appear in abundance in the fine-grained sandstones of P2. The arenites of the youngest unit P1 have modal grain size ranging from very fine to coarse sand, and in places are bimodal. The rock grades vertically into subgreywacke.

Tourmaline, zircon, and collophane, are present as accessories. The cement is commonly siliceous; having been formed by pressure welding, solution, and development of quartz overgrowths. Calcite, and less commonly glauconite, anhydrite, and dolomite cements are present. Clay is predominantly illitic and kaolinitic, with minor chlorite.

TABLE 12. THICKNESSES OF THE PACOOTA SANDSTONE UNITS (SUBSURFACE)

Locality No.	Well Name	P1		P2		P3		P4		Total	
		ft	m	ft	m	ft	m	ft	m	ft	m
1	Alice 1	207+	63.1	178	54.3	310	94.5	194	59.1	889+	271+
2	East Johnny's Creek 1	123	37.5	360	109.7	230	70.1	213	64.9	926	282.2
3	East Mereenie No. 1	354	107.9	221	67.4	265	80.8	235	71.6	1075	327.7
4	East Mereenie No. 2	268	81.7	219	66.7	275	83.8	185+	56.4+	947+	288.7+
5	East Mereenie No. 3	313+	95.4+							313+	95.4+
6	East Mereenie No. 4	287	87.5	218	66.5	280	85.3	194	59.1	979	298.4
12	Mereenie No.1	283+	86.3+							283+	86.3+
14	Northwest Mereenie No.1	300	91.4	250	76.2	250+	76.2+			800+	243.8+
17	Orange No. 1	325	99.1	395	120.4	350	106.7	170	51.8	1240	378
18	Palm Valley No. 1	248	75.6	278	84.7	244	74.4	254+	77.4+	1024+	312.1+
19	Palm Valley No. 2	2+	0.6							2+	0.6+
20	Palm Valley No. 3	253	77.1	235	71.6	324	98.8	371+	113.1+	1183+	360.6+
23	West Mereenie No. 1	288	87.8	234	71.3	274	83.5	229	69.8	1025	312.4
24	West Mereenie No. 2	344	104.9	246	75	274	83.5	167	50.9	1031	314.3
25	West Waterhouse No.1	227	69.2	320	97.5	108+	32.9+			655+	199.6

Isopachs and Lithofacies

The restored isopach map (Fig.10) of the Pacoota Sandstone indicates the formation is wedge shaped, thick and extensive, thinning to the south and southwest at the rate of about 7.5 m per km. The present northern limit is an erosional margin. The base map of the basin has been derived by palinspastic readjustment.

The Pacoota Sandstone has a maximum thickness of 914 m at the Finke River (loc. 54) and 823 m at its type locality at Ellery Creek.

Lithofacies map of the Pacoota Sandstone has a distinctive median area of high shale content trending east-west in the central area of the basin and northeasterly in the northeastern part of the basin. The median 'channel' area extends westward at least as far as the Mereenie Field area.

The lithofacies is limited to sandstone-shale assemblage (Table 13).

Depositional Environment

The fauna, the abundant cross-beds and ripple marks, and the presence of glauconite indicate that the Pacoota Sandstone is a shallow-marine deposit (Wells et al. 1970).

The symmetrical distribution of sandstone i.e. shale lithofacies about a central high shale area suggests that a marine channel existed in the basin. Palaeocurrent directions (Williams et al. 1965) and pebble grain size distribution indicate that sediment transport and source areas were mainly from the west.

A much thicker sequence of clastics to the north of the channel way, containing conglomerates and breccias, indicates that a highly elevated landmass existed probably to the west and that it shed sediments eastward into a periodically sinking median depression.

The zero isopach in the south probably represents the southern shore-line. The thinner sequence of sediments indicates that either the landmass had been completely denuded prior to commencement of Pacoota


RESTORED ISOPACH & LITHOFACIES MAP
PACOOTA SANDSTONE - AMADEUS BASIN
0
50
100km
Well locality
328
Thickness (metres)
79
Outcrop locality
Thickness (metres)
Isopach interval 100 metres
Area in which Glauconite occurs
LITHOFACIES INDEX
25% shale
50% sandstone
25% unexposed
> 20% shale
> 40% shale
To accompany Record
Author L.E. Kurylowicz
Date February 1975
Fig. 10
200
100
0
128°00
129°00
130°00
131°00
132°00
133°00
134°00
135°00
136°00
24°00
25°00
26°00

Table 13. Pacoota Sandstone Lithofacies

Locality No.	% Sand	% Shale	% Exposed	Glauconite
1	70	30		A
2	70	30		P
3	75	25		P
4	73	27		P
6	53	47		P
14	73	27		P
17	54	46		P
18	32	68	incomplete	P
20	43	57		P
23	61	39		P
24	47	53	incomplete	P
25	51	49	incomplete	P
30	40		40	A
31	84		84	A
32	15		15	A
33	50		50	A
34	80		80	A
35	62		62	A
36	45		45	P
37	70	10	80	A
38	73	2	75	A
39	50		50	A
40	75	10	85	A
41	100		100	A
42	100		incomplete	
43	51		51	A
44	15		15	
45	90	10	100	P

P - Present A - Absent

Table 13 contd. Pacoota Sandstone Lithofacies

Locality No.	% Sand	% Shale	% Exposed	Glauconite
46	45		45	
48	33		33	A
51	85	15	100	A
52	100		100	A
53	78		78	A
54	88		88	A
55	100		100	A
56	100		100	A
57	100		100	A
58	100		100	A
59	100		100	A
60	100		100	A
61	84	16	100	A
62	100		100	A
63	100		100	A
64	80	10	90	A
65	100		100	A
66	100		100	A
68	100		100	A
71	100		100	A
72	67		67	P
73	90		90	A
75	100		100	A
79	100		100	
81	85		85	A
82	100		100	
85	40		40	P
86	90		90	
89	85	5	90	P
91	75	5	80	
93	85	5	90	

deposition resulting in little topographic relief or that basement sinking did not keep pace with the rate of sediment supply.

The thick and extensive 'blanket type' orthoquartzites of the Pacoota Sandstone (like those of P4) were probably formed by the coalescing of longshore bars (Scolithus restricted to littoral sands facies), particularly in the southern marginal area, during repeated minor transgressions and regressions.

Williams et al. (1965) has suggested that some of the quartz grains showing aeolian frosting were presumably blown into the longshore fan areas from beach dunes. However, Well et al. (1970) consider it more likely that the frosting of grains is the result of chemical weathering and diagenesis.

The thick 'blanket type' deposition of the Lower Pacoota Sandstone, was followed by progressively more marine conditions; the process of deposition probably consisted of a sequence of marine transgressions and regressions, each transgression being a little more extensive and each subsequent regression being a little less extensive than the former. The cleaner transgressive sandstones (P3 to P1) probably represent the destruction of beach deposits by surf and wave action, as the sea migrated over the land. The fining upwards of the sandstones, their decrease in thickness, together with the increase in intervening shale suggests that sediment supply, probably from the southern landmass, was less effective as the shore line became more distant and water depths greater.

Middlemiss (1962) suggests that the straightness of burrows indicates rapid deposition, the burrowing organism being able to keep pace with rapid sedimentation by 'straight chewing'. Application of this criterion to the Pacoota Sandstone, in which Scolithus is common, suggests that sedimentation was rapid at first but somewhat slower in the upper part of the section, where Scolithus is less common. Arenites may have acquired their supermaturity during the period of slow deposition.

Williams et al. (1965) suggested from palaeocurrent data that there is divergence of current directions around some anticlines, such as the Waterhouse Range. Also gamma ray correlation of the Larapinta Group shows that there was thinning over the Mereenie Anticline. These anticlines probably formed topographic ridges during the latter part of Pacoota Sandstone time.

Horn Valley Siltstone

Definition

Prichard and Quinlan (1962, p.20) defined the Horn Valley Formation "as the siltstone containing thin limestone beds which conformably overlies the Pacoota Sandstone and is conformably succeeded by the Stairway Greywacke". Wells et al. (1962) renamed the formation the Horn Valley Siltstone.

Type Locality

Ellery Creek (locality 55)

Outcrop Lithology

The Horn Valley Siltstone contains siltstone, calcareous siltstone, claystone, limestone, and minor sandstone and sandy siltstone.

At Ellery Creek (loc. 55), the base of the Horn Valley Siltstone is at the top of a hard quartzite bed (Pacoota Sandstone). The formation is a 55 m thick siltstone containing thin beds and lenses of quartz sandstone and poorly sorted, silty quartz sandstone, some of which are glauconitic (Prichard & Quinlan, 1962). The sequence is followed by 73.2 m of siltstone interbedded with thin, very fossiliferous, greenish limestone beds. A few fossils occur in the siltstone, which is marly towards the top. The top 6.1 m of the formation consist of soft siltstone and poorly sorted, silty, fine-grained quartz sandstone, which are conformably overlain by the hard beds of the Stairway Sandstone.

The siltstone and claystone are predominantly grey-green and pale brown in outcrop (Wells et al. 1970). They are laminate to thinly bedded, calcareous in part, soft and readily weathered, pyritic, and possibly gypsiferous. (The selenite which forms a superficial deposit in places over the Horn Valley Siltstone may have been derived by recrystallization of primary gypsum which was dissolved by percolating waters.)

The ratio of calcareous to non-calcareous sediments (Fig. 11) ranges from 1:2 to 1:0, with the highest proportion of calcareous sediments in the south and west.

The limestone is yellow-brown, grey-brown, or dark grey in outcrop; it is thin-bedded, brittle, moderately resistant to weathering, rarely sandy, and largely composed of fossil fragments. The limestone is recrystallized and veined by calcite in places.

The (subordinate) sandstone is brown or grey brown, thin-bedded, silty, friable, and easily weathered. Glauconite is rarely present in the sandstone and limestone. A few bands of pelletal phosphorite, similar to those in the Stairway Sandstone, are present towards the top of the formation. A distinctive band of oolitic ironstone is also present near the top of the formation (Wells et al. 1970 p. 70) and although it is generally only a few inches thick, it extends over thousands of square kilometres. The ooliths are limonitic in outcrop, but pyritic when fresh. The prominent oolitic limonite band crops out in the Levi Range (loc. 63) and in the vicinity of the Liddle Hills (near loc. 61). Because of the poor exposure, the total thicknesses of the oolitic ironstone is uncertain and there may be several thin oolites interbedded with yellow and brown very fine - grained sandstone.

In the northern halves of the Lake Amadeus and Henbury Sheet areas, the Horn Valley Siltstone lies apparently conformably between the Pacoota Sandstone and overlying Stairway Sandstone, but in places in the south (e.g. Seymour Range loc. 70, 74) the formation lies disconformably on the

Pertaoorrta Group. In the Waterhouse Range (loc. 81) and in the James Range east of Mt. Peachy the Horn Valley Siltstone is disconformably overlain by the Mereenie Sandstone.

Subsurface Lithology

The Horn Valley Siltstone consists of dark grey to black siltstones and shales interbedded with scattered limestone and dolomite beds. The base of the Horn Valley Siltstone is distinguished often by a biofragmental glauconitic dolomite bed (up to 5 m thick) e.g. East Mereenie No. 1, Palm Valley No. 1, West Waterhouse No. 1. The dolomite interbeds are usually dark grey to black, crypto to finely crystalline. The limestone interbeds are white to grey, crypto to finely crystalline and fossiliferous.

An oolitic ironstone band (similar to that in outcrop) has been intersected in AP1, AP2, AP3, (loc. 26,27,28) and in Palm Valley No. 3 (loc. 20). Cores show that the limonite has been formed by the weathering of pyrite (Ranford et al. 1965 p. 26).

Age

Stelck and Hopkins (1962) report that the Horn Valley Siltstone contains a Lower Ordovician fauna of ellesmereoceratids, endoceratids, crythochoanitic straight nautiloids, asaphid trilobites, *Raphistomina*, *Lophospira*, *Palaearca*, *Ctenodonta*, orthid brachiopods, plectambonitids, *Lingulella* (?) and graptolites. Joyce G. Tomlinson in (Wells et al. 1970) states that this rich and extremely well preserved fauna indicates a Lower Ordovician (Arenigian) age.

Petrography

The limestones of the Horn Valley Siltstone are composed largely of fossil fragments (bivalves, graptolites) with a sparry calcite cement. Anhydrite and gypsum occur in the Palm Valley area. They are classified as biosparites, biosparrudites, and less commonly biosparmicrites (Appendix I).

The quartz in the calcerous sandstone, siltstone, and sandy limestone is angular and moderately to well sorted. It is mainly non-undulatory quartz. Glauconite, glaucophane, muscovite, and zircon occur as accessories, limonitic oolites are present in Lake Amadeus No. 1 well. The clays are mainly illite and kaolinite.

Isopachs and Lithofacies

The restored isopach and lithofacies map of the Horn Valley Siltstone (Fig. 11) is based upon the palinspastic base map (Fig. 9).

The Horn Valley Siltstone is a thick and extensive wedge shaped body having its maximum thickness of 448 m at Goyder Pass (loc. 53) on the northern eroded margin. The formation thins to the south at a rate of about 2.7 m per km.

Along the northern margin, the formation also thins quite rapidly at a rate of 3.8 m per km from 448 m at Goyder Pass (loc. 53) to 134 m at the type locality, Ellery Creek (loc. 55).

The lithofacies distribution indicates a high non-carbonate : carbonate area in north-central part of the basin. Areas of relatively high carbonate content (7:1) exist in the south and in the west (See Table 14).

In the south, a high sandstone percentage area is present; it coincides in part to the high carbonate area in the south, and extends to the west of it. Another area of high sandstone content is present in the north (Fig. 11).


RESTORED ISOPACH & LITHOFACIES MAP
HORN VALLEY SILTSTONE – AMADEUS BASIN
0
50
100 km
23 Well loc lity
100 Thicknes (metres)
79 Outcrop ocality
14 Thicknes (metres)
50 Isopach terval 50 metres
3:1 Non-cart nate:carbonate ratio
LITHOFACIES INDEX
25% shale
25% sandstone
25% carbonate
25% unexposed
To accompany Record
Author L E Kurylowicz
Date February 1975
Fig. 11
128°00'
129°00'
130°00'
131°00'
132°00'
133°00'
134°00'
135°00'
136°00'
23°00'
24°00'
25°00'
26°00'

Table 14. Horn Valley Siltstone Lithofacies

Locality No.	% Sand	% Shale	% Carbonate	% Exposed (outcrop)
-	-	-	-	
2	-	78	22	
3	-	80	20	
4	-	82	18	
5	8	70	22	
6	-	85	15	
14	-	66	34	
17	29	71	-	
18		80	20	
19		80	20	
20	-	83	17	
23	-	77	23	
24	-	83	17	
25	-	84	16	
26	-	91	9	
27	-	74	26	incomplete
28	-	100		incomplete
31	-	57	10	67
33			10	10
36		1		1
37	25	40	5	70
38	2	20	2	24
40	40	30	30	100
41	50	44	6	100
44		1	1	2
45	30	40	30	100
48			1	1
51	40	48	12	100
52	25			25

Table 14 contd. Horn Valley Siltstone Lithofacies

Locality No.	% Sand	% Shale	% Carbonate	% Exposed (outcrop)
53	43	43		86
54		65		65
55		100		100
59		65	35	100
60		75	25	100
62		68	32	100
63	40	30	30	100
65		75	25	100
67		10		10
69	50		50	100
71	30	30	40	100
72		1	12	13
73	70			70
74	50	50		100
75		75	25	100
78	40	40	20	100
79	50	50		100
80		50	50	100
81		75	25	100
82		80	20	100
89		50	20	70
91		25	10	35
93		85		85

Depositional Environment

The Horn Valley Siltstone is marine. The abundance of graptolites (Wells et al. 1970 p. 71) suggests that the upper waters were well aerated and able to support a prolific fauna; the lack of indigenous fauna and the extremely good preservation of the numerous fossils suggest euxinic conditions on the sea bottom. The presence of pyrite also suggests strongly reducing bottom conditions, as do the foetid smell, the black colour, and the abundance of organic carbon (D.M. McKirdy, pers. comm.).

The isopach and lithofacies map (Fig. 11) indicates a broader marine area than that in Pacoota Sandstone time. A fluvial system from the south (high sandstone area) was present providing the major sediment supply.

Shallow marine conditions with wave and winnowing action prevailed in the south (high sandstone and limestone lithofacies), whereas tranquil deeper water, marine conditions prevailed in the central and northeastern areas. Folk (1961) considered that biosparites indicate fairly strong winnowing action during or immediately after deposition of calcareous sediments.

Near the end of Horn Valley Siltstone deposition, shallowing of large areas of the basin (regression) occurred. (Viz. the formation of pyritic oolites over a large area). Also, the presence of anhydrite and gypsum in the (Palm Valley area) indicates partly restricted marine conditions.

Stairway Sandstone

Definition

Prichard and Quinlan (1962, p. 21) defined the Stairway Greywacke as "the formation of quartz greywacke and quartz sandstone which at Ellery Creek conformably overlies the Horn Valley Formation and is there followed unconformably by the Mereenie Sandstone". Wells et al. (1962) renamed the formation the Stairway Sandstone.

Type Locality

Ellery Creek.

Outcrop Lithology

The dominant lithology of the Stairway Sandstone is quartz sandstone. Cook (1966) has subdivided the formation into lower, middle, and upper units on the basis of lithology. All three units are present in the northern half of the basin, but in the south only the uppermost unit is present.

The lower unit of the Stairway Sandstone shows little lateral variation in lithology or thickness; its maximum thickness is 650 m in the northern eroded limit of the basin. It is white or grey, fine to very coarse-grained sandstone, with well rounded and well sorted quartz grains. It is pebbly in places, and one pebble band, and 0.3 m thick, forms a useful marker over an area of at least 26,000 km^2 in the Rodinga, Henbury, and Lake Amadeus Sheet areas (Wells et al. 1970). The sandstone is thinly to massively bedded, ripple-marked and cross-bedded. Bedding-plane markings, tracks and trails are common. Also, the common occurrence of pipe-rock (vertical worm tube? Scolithus) makes it difficult to distinguish it from some of the pipe-rock in the Pacoota Sandstone. In places, the sandstone near the base of the unit contains up to 20 percent of ooliths, which are pyritic subsurface but limonitic in outcrop. The lower unit of the Stairway Sandstone is a typical blanket sand.

The middle unit contains siltstone, mudstone, and claystone, which are black subsurface but grey or green in outcrop. The lutites are commonly sandy, micaceous, laminate, easily weathered and poorly exposed. Grey or white, fine-grained, thin-bedded sandstone and grey, brown, or black pelletal and nodular phosphorites are interbedded with the lutites. The middle unit shows a marked lateral variation, and the lutite - arenite - phosphorite sequence passes into a lutite and carbonate sequence to the southeast (Seymour Range area). The carbonate rocks in the southeast include thin-bedded, dark grey limestone and dolomite which contains a distinctive fauna of small pyritized gastropods. Farther east, the middle unit is composed mainly of red lutites and arenites. Rare occurrences of phosphorites are reported in both the carbonate and red-bed facies.

The upper unit is predominantly an arenite sequence and its lithology is similar to the lower unit. Nodules of phosphorite and manganese occur in the basal conglomerate in the Mount Sunday Range. The arenites consist predominantly of white or grey, fine-grained, silicified sandstone; they are cross-bedded, and commonly contain abundant trace fossils such as Diplocraterion and Cruziana.

Subsurface Lithology

A tripartite subdivision of the Stairway Sandstone is evident also in the subsurface; a lower coarse sandstone, a middle phosphatic lutite unit, and an upper fine sandstone with minor siltstone. Abundant pyrite up to 2.5 mm in diameter nodules are present in the lower unit in West Waterhouse No. 1 (loc. 25), AP2 (loc. 27), and at AP3 (loc. 28). Coarse grained, well rounded, frosted quartz grains are reported from the Mereenie field area (loc. 3, 12) and from Gosses Bluff No. 1 (loc. 8).

The middle unit comprises black to grey siltstone and shale with minor sandstone. Some intervals are calcareous as at Northwest Mereenie No. 1 (loc. 14) and Orange No. 1 (loc. 19). Dark phosphatic pellets, slumps, worm burrows, and trails are common.

The upper unit is predominantly a white, fine-grained sandstone. Minor thin siltstone/shale bands are present in places. Some slumps, burrows, trails, and few bands of sparse phosphate pellets and grains of phosphate are present. The thicknesses of the individual units of the Stairway Sandstone are given in Table 15.

Age

The Stairway Sandstone is estimated to range from Upper Llanvirnian to Llandellian (Wells et al. 1970). The rich fauna includes trilobites, brachiopods, pelecypods, gastropods, nautiloids, sponge spicules, numerous trace fossils, and microfossils. Diplocraterion worm tubes (Stelck & Hopkins, 1962) take the place of scolithids as found in the Pacoota Sandstone.

Petrography

The arenites of the lower unit of the Stairway Sandstone are generally well sorted, coarse-grained, the grains being well rounded. Bimodality is common, and the two modes are each well sorted. The arenites are predominantly quartzose grading to feldspathic sub-labile in the southern part of the basin (Appendix I).

The arenites of the middle unit are very fine-grained, texturally immature (clay 5%) and supermature mineralogically (quartzose).

The quartzose arenites of the upper unit are very fine-grained, well sorted with subangular to rounded quartz grains. The arenites become feldspathic in the south (abundant fresh euhedral microcline). Well rounded tourmaline and zircon grains are present as accessories together with smaller amounts of apatite and muscovite.

The lutites (mostly in the middle unit) include both siltstone and claystone. The lutites are quartzose and feldspathic, poorly sorted, and angular. Illite is the predominant clay mineral.

Wells et al. 1970 report that the limestone and dolomite within the Stairway Sandstone contains appreciable amounts of terrigenous quartz. The limestones are mainly micrites and biomicrites, and the dolomites are generally aphanocrystalline to coarsely crystalline.

TABLE 15. THICKNESSES AND LITHOFACIES OF THE MEMBERS OF THE STAIRWAY SANDSTONE

Locality No.	Thickness in metres			Lithofacies		
	Upper	Middle	Lower	Upper ss:sh	Middle ss:sh	Lower ss:sh
3	49	126	65	90:10	5:95	80:20
4	51	122	56	80:20	30:70	75:25
5	54	127	69	80:20	45:55	85:15
6	49	136	63	90:10	15:85	70:30
14	55	126	94	90:10	0:100	75:25
18	27	142	133	95:5	30:70	70:30
19	26	151	119	100:0		
20	31	148	131	90:10	15:85	60:40
23	44	140	76	100:0	0:100	80:20
24	50	123	70	90:10	10:90	75:25
25	21	81	123	80:20	35:65	60:40
26	40	87	60	85:15	0:100	100:0
27	20+	81	59	100:0	15:85	95:5
28	29+	107	95	95:5	20:80	90:10
29	52	A	A	85:15		
31	6+	10	19			
34	22	95	35			
36	34	79	38	100:0	40:60	100:0
37	124	109	63	40:60	30:70	100:0
40	291	107	163	100:0	0:100	100:0
41	?15	?30	3?			
44	23	82	52	100:0	0:100	100:0
45	42	139	78	100:0	0:100	100:0
49	30	A	A	?50:50	red beds: remainder	
51	259	107	91	100:0	25:75	80:20
54	250	128	49	60:40	75:25	50:50
55	56+	207	61	40:60	30:70	100:0

Table 15 cont.

56	76	76	61		ss:sh 45:55	100:0
61	120+	A	A	40:60		
70	97	37	A	60:40	ss:sh:carb red beds:remainder	
71	85	67	76	60:40	40:60	100:0
80	24	46	27	100:0	100:0	100:0
83	105	A	A	90:10		
84	68	A	A	100:0		
94	34	30	29	100:0	redbeds:remainder 100:0	100:0
95	11+	27	31	100:0	100:0	100:0

Cook (1966) has described 10 distinctive types of phosphorite. The most common forms are pellets showing no internal structure or sandy pellets showing no internal structure or sandy pellets containing up to 60 percent detrital quartz grains. Other modes of occurrence include pellets with concentric banding; composite pellets composed of smaller pellets; structured pellets with an irregular (commonly convoluted) internal form; and encasing pellets which form a thin skin around detrital grains (generally quartz). Phosphate also occurs as a cement, as phosphatized fossils, and as secondary minerals.

Isopachs and Lithofacies

The restored isopach and lithofacies map of the lower Stairway Sandstone (Fig. 12) shows an east-west trending depocentre containing up to 150 m of sediment in the northern part of the basin. A shaly facies (>25% shale) corresponds with the depocentre area (see also Table 16). The zero isopach in the south probably represents the depositional shoreline.

The map of the middle Stairway Sandstone (Fig. 13) shows a northeast-southwest trending depocentre (over 200 m) in the northern part of the basin. The zero isopach in the south and southwest probably represents the shoreline. The lithofacies varies from red-bed (lutile-arenite) in the east, through carbonate facies to a lutite facies in the west. Phosphorites occur in all three facies.

The restored isopach and lithofacies map of the upper Stairway Sandstone (Fig. 14) and the total Stairway Sandstone map (Fig. 15) show marked thickening to the north. The upper unit is 291 m thick at Idirriki Range (loc. 40) and thins to 52 m at BMR AP4 phosphate bore (loc. 29). A shaly facies (>25% shale) is present in the median trough area which trends northeast-southwest in the northern part of the basin.


RESTORED ISOPACH & LITHOFACIES MAP
MIDDLE STAIRWAY SANDSTONE - AMADEUS BASIN
0
50
100km
27 Well locality
81 Thickness (metres)
55 Outcrop locality
207 Thickness (metres)
—100— Isopach interval 25metres
LITHOFACIES INDEX
50% shale. 25% sandstone
25% carbonate
OR
50% remainder 50% red beds
Area of carbonate facies
Area of red beds facies
To accompany Record
Author L.E. Kurylowicz
Date: April 1975
Fig. 13


RESTORED ISOPACH & LITHOFACIES MAP
UPPER STAIRWAY SANDSTONE–AMADEUS BASIN
0
50
100km
14
55
Well locality
Thickness (metres)
84
68
Outcrop locality
Thickness (metres)
—25— Isopach interval 25 metres
LITHOFACIES INDEX
25% shale 75% sandstone
> 25% shale
To accompany Record
Author: L.E. Kurylowicz
Date: April 1975
Fig. 14

RESTORED ISOPACH & LITHOFACIES MAP
TOTAL STAIRWAY SANDSTONE - AMADEUS BASIN
0
50
100km
14 Well locality
275 Thickness (metres)
79 Outcrop locality
130 Thickness (metres)
50 Isopach interval 50 metres
Limit of shale deposition
LITHOFACIES INDEX
25% shale
25% unexposed
50% sandstone
> 25% shale
> 50% shale
> 75% shale
To accompany Record No
Author: L.E. Kurylowicz
Date: February 1975
Fig. 15
128°00
129°00
130°00
131°00
132°00
133°00
134°00
135°00
136°00
23°00
24°00
25°00
26°00

Table 16. Stairway Sandstone Lithofacies

Locality No.	% Sand	% Shale	% Carbonate	% Exposed (outcrop)
2	95	5		
3	45	55		
4	47	53		
5	49	51		
6	23	77		
8	60	40		
14	77	23		
17	100			
18	55	45		
19	54	46		
20	52	48		
21	47	53		
23	37	63		
24	42	58		
25	49	51		
26	54	46		
27	71	29		
28	69	31		
29	82	18		
31	68			68
33	80			80
34	12		3	15
35	4	1		5
36	47			47
37	60	40		100
38	52			52

Table 16. Stairway Sandstone Lithofacies
contd.

Locality No.	% Sand	% Shale	% Carbonate	% Exposed (outcrop)
39	100			100
40	75	5		80
41	100			100
42	43			43
43	52	8		60
44	29		1	30
45	70	30		100
48	31	30	2	62
49	100			100
50	17			17
51	90	10		100
52	15			15
53	70	20		90
54	83			83
55	100			100
56	80	20		100
57	80	20		100
58	60			60
59	65	35		100
60	100			100
61	?100			incomplete
62	36	64		100
63	80	20		100
64	60			60
65	100			100
66	100			100
67	20	20		40
68	25	25		50

Table 16 contd. Stairway Sandstone Lithofacies

Locality No.	% Sand	% Shale	% Carbonate	% Exposed (outcrop)
69	80	20		100
70	80	20		100
71	50	40		90
72	26	2	1	29
73	25			25
74	60	40		100
75	60	40		100
76	80	20		100
77	80	20		100
78	80	20		100
79	80	20		100
80	80	20		100
82	90	10		100
84	55	15		70
89	72	3		75
90	87	3		90
91	85	5		90
92	90	10		100
93	85	5		90
94	95	5		100
95	75.	10		85

Depositional Environment

The coarseness of the sand grains in the lower unit of the Stairway Sandstone and the high degree of rounding and sorting suggest that the orthoquartzite was deposited in a vigorous environment, or, less probably, that the rate of sedimentation was so slow that the efficiency of the rounding and sorting mechanism matched the rate of deposition (Wells et al. 1970 p. 16). The bimodality suggests that sediments from different environments were mixed. The orthoquartzite of the upper unit was probably deposited in much the same but less vigorous environment. A barrier island or a beach are environments which would produce this type of sandstone, and (the body of) blanket sand was probably formed by the coalescing of elongated bodies of sand.

The presence of phosphorites and the abundance of bioturbation (suggested by Middlemiss, 1962, as an indication of the rate of deposition) suggest that the middle unit was probably laid down very slowly. The presence of pyrite, organic matter, and phosphorites suggests that the pH ranged from 7.0 to 7.8 (Krumbein & Garrels, 1952), and the Eh from -0.2 to -0.4, that is, strongly reducing, but possibly becoming more oxidizing to the south east. These conditions are consistent with a poorly aerated lagoonal environment.

Detailed studies of the Stairway Sandstone (Cook, 1966) using the graphic log method of Bouma (1962), suggest either a lagoon-barrier island environment of the Laguna Madre type (Rusnak, 1960), or an intertidal-flat environment of the Wash type (Evans, 1965). Both these environments today are restricted in areal distribution, whereas the original area of deposition of the Stairway Sandstone was probably at least 100,000 square kilometres. Irwin (1965) and Shaw (1964) have suggested a model for epeiric sea sedimentation. They envisaged wide low-energy open-sea and landward (middle unit) environments and a narrow high-energy environment where the open-sea waves impinge on the epeiric sea floor (which may have been the depositional environment of the lower and upper units of the Stairway Sandstone).

Stokes Siltstone

Definition

Wells et al. 1970 redefined the Stokes Siltstone as "a sequence of grey and green siltstone and claystone with minor thin-bedded limestone and a few sandstone interbeds which lies conformably between the Stairway Sandstone below and the Carmichael Sandstone above. The base of the Stokes Siltstone has been selected at the top of the last major sandstone in the Stairway Sandstone. The top is taken at the base of the first prominent sandstone of the Carmichael Sandstone." The Stokes Siltstone differs from the Stokes Formation of Prichard & Quinlan, (1962) in that it does not include a silty red-brown sandstone (now known as the Carmichael Sandstone) at the top of the formation.

Type Locality

Stokes Pass (loc. 51)

Outcrop Lithology

The Stokes Siltstone is composed of siltstone and claystone, with minor limestone and sandstone.

The lutites are generally green, grey-green, or pale brown in outcrop. In places they are micaceous, sandy, or calcareous; they are generally laminate or thin-bedded, and easily weathered. Abundant pseudomorphs after halite occur in the lutites.

The limestones which are more common in the lower half of the formation, are pink, grey, or grey-green, thin-bedded, moderately resistant to weathering and generally composed of a large number of fossil fragments (coquinites).

The Stokes Siltstone is rarely exposed, and generally forms wide alluvium-covered valleys. The only areas where it is well exposed are in the western MacDonnell Ranges, at the extreme western end of the Johnny Creek Anticline, and on the flanks of the anticlines west of Tempe Downs homestead. The formation has been eroded by the Alice Springs Orogeny east of a line joining Ellery Creek (loc. 55) and Mt Peachy area (loc. 91).

The Stokes Siltstone overlies the Stairway Sandstone with a conformable and gradational contact, except on the extreme western margin of the basin, where it unconformably overlies the Bitter Springs Formation and other Proterozoic units. In the west, it is overlain by the Carmichael Sandstone; the contact is both conformable and gradational. To the east, it is unconformably overlain by the Mereenie Sandstone.

Subsurface Lithology

The Stokes Siltstone consists predominantly of shale and siltstone, with minor dolomite, limestone and gypsum.

The lutites are generally red, brown, and green, and laminated. The dolomite and limestone which mainly occur near the base are mostly white, crypto-to finely crystalline, and contain biofragments including bryozoa, brachipods, and crinoid stems (e.g. Gosses Bluff, loc. 8). Minor oolites have been reported from East Mereenie No. 1 (loc. 3) and Mereenie No. 1 (loc. 12).

Age

Fossils are fairly common, particularly in the limestone, but most of them are fragmentary. They include brachiopods, trilobites, gastropods, pelecypods, echinoderms, nautiloids, conodonts, and some trace fossils. The most characteristic fossil is the brachiopod Orthis leviensis. The fossils are of Upper Ordovician (Caradocian) age (Joyce G. Tomlinson, in Wells et al. 1970).

Stelck and Hopkins (1962) state that coquinoids present in the lower part of the Stokes Siltstone contain brachiopods including Orthid leviensis, straight nautiloids, Lophospira and nuculid pelecypods.

Petrography

The terrigenous material in the lutites and arenites is predominantly fine to very fine-grained, moderately sorted, subrounded, non-undulating quartz (Appendix 1). The dominant clay is illite, with minor chlorite, and some limonite? (red colour). Muscovite is also present in some thin sections.

The commonest type of limestone is a biomicrite or a biomicrudite (Wells et al. 1970), in which the fossil fragments are embedded in a microcrystalline calcite cement. In places the cement is sparry, or patches of sparry calcite occur within a predominantly microcrystalline calcite cement, possible owing to disturbance of the matrix by boring organisms. Some of the limestones are composed mainly of fossils belonging to one phylum: e.g. echinoid biomicrites are common.

Isopach and Lithofacies

The restored isopach map of the Stokes Siltstone (Fig. 16) indicates that the formation is a wedge shaped body with the thickest section of 610 m at Stokes Pass (loc. 51). The formation is eroded along the northern margin of the basin. The formation thins to the west, south, and east at the rate of about 2.5 m per km. A north-south trending channel, joining localities 51 to 56, is present in a generally southerly thinning wedge of rock.

RESTORED ISOPACH & LITHOFACIES MAP
STOKES SILTSTONE – AMADEUS BASIN
0
50
100km
14 Well locality
356 Thickness (metres)
79 Outcrop locality
229 Thickness (metres)
—100— Isopach interval 100 metres
Limit of carbonate deposition
LITHOFACIES INDEX
25% shale
25% sandstone
25% carbonate
25% unexposed
NO CARBONATES
LIMIT OF CARBONATE DEPOSITION
128°00'
129°00'
130°00'
131°00'
132°00'
133°00'
134°00'
135°00'
136°00'
23°00'
24°00'
25°00'
26°00'
To accompany Record
Author: L.E. Kurylowicz
Date: February 1975
Fig. 16

Areas of non-carbonate deposition are restricted to a central northwest-southeast trending area of high shale content, and to the western, southern and eastern marginal areas of the basin. Also, three areas of high sandstone content have been detected (Fig. 16) they are in the northern, south-western and southern parts of the basin. (See Table 17).

Depositional Environment

The presence of crinoid stems, and lutaceous character of the sediments suggests that marine conditions of deposition were generally tranquil.

The pseudomorphs after halite suggest abnormally high salinities, possibly resulting from restriction of circulation by a topographic barrier, followed by evaporation. There is, however, no evidence of a topographic barrier in the Amadeus Basin during Stokes Siltstone time, and Well et al. (1970) consider it unlikely that a lagoon with an areal extent of some 150,000 square kilometres existed. It is possible that the high salinity resulted from the lack of ocean currents in a broad and very shallow sea (Shaw, 1964). Owing to their higher density, the more saline waters sank to form supersaline bottom waters in which large halite crystals were formed at the sediment-water interface or just below.

The three sandstone areas depicted on the lithofacies map may indicate areas of fluvial systems originating from northern and southern landmasses.

It is assumed that the seaway was common between the Amadeus Basin and the Canning Basin to the west during the latter part of the Ordovician and the expulsion of the sea was finally through the Canning Basin as the rise of the "Arunta" arch uplifted the eastern end of the Amadeus Basin, thus cutting off access to the Georgina Basin to the northeast.

Table 17. Stokes Siltstone Lithofacies

Locality No.	% Sand	% Shale	% Carbonate	% Exposed (outcrop)
2	-	-	-	
3		95	5	
4	1	90	9	
5		87	13	
6	2	85	13	
8		88	12	
12		86	14	
14		96	4	
18	2	98		
19	4	96		
20		94	6	
21		93	7	
23	2	85	13	
24		94	6	
25		91	9	
26	40	60		incomplete
29		100		
37	5	20	15	40
38		3		3
40	30	40	30	100
			14	14
45	70	30		100
47		?84		incomplete
48	1	3	2	6
50		28	1	29
51	20	30	10	60
52	20			20
53	8	7		15

Table 17 contd. Stokes Siltstone Lithofacies

Locality No.	% Sand	% Shale	% Carbonate	%Exposed (Outcrop)
56		75	25	100
57		5	10	15
58	5	10	5	20
59		10	10	20
62	20	80		100
63	40	35	25	100
68	12			12
71		30	20	50
75		10	10	20
77	20	20	5	45
78	13	13		26
79	30	40	30	100
80		80	20	100
84	10	35		45
89				0
90		present	present	incomplete
92		100		incomplete

Carmichael Sandstone

Definition

Wells et al. 1970 named the Carmichael Sandstone as "a sequence of brown and red-brown cross-bedded sandstone, and silty sandstone with interbeds of red-brown siltstone and claystone, which conformably overlies the Stokes Siltstone and is unconformably overlain by the Mereenie Sandstone. The bottom of the Carmichael Sandstone is at the base of the first major sandstone; the top is at the change from poorly sorted silty sandstone and siltstone to the clean well sorted sandstone of the Mereenie Sandstone".

Type Locality

One mile south of Langs Well on the north side of George Gill Range (locality 47).

Outcrop Lithology

The Carmichael Sandstone is composed mainly of red-brown, yellow, purple-brown, and pale brown cross-bedded sandstone and silty sandstone with interbeds or red-brown siltstone and claystone. The sediments are moderately to poorly sorted, and become more coarse to the south. The sandstone is thinly to thickly bedded, and ripple marked in places. Mud cracks and halite pseudomorphs occur in the silty sandstone and sandstone.

Interbeds of siltstone and claystone are common throughout the formation; they are red-brown or green in outcrop, micaceous in part, thinly bedded or laminate, and poorly exposed.

The Carmichael Sandstone crops out sporadically over a large area (Wells et al. 1970, p.80, fig. 31). The western limits of the formation are uncertain, but it is thought to have an extent similar to that of the Stokes Siltstone. In the south, it may be more extensive than the underlying Stokes Siltstone, having been deposited beyond the accepted, southern erosional margin of the basin.

In the east, the formation was removed by the erosion that followed the Rodingan Movement.

The Carmichael Sandstone is generally poorly exposed. It commonly underlies the steep scree-covered slopes below the Mereenie Sandstone scarps and is only exposed in the creek beds cutting through the scree.

Subsurface Lithology

In well sections, the Carmichael Sandstone is predominantly red to orange and sometimes white, poorly to medium sorted, argillaceous, micaceous, and silty. The grain size varies from fine to granular. Minor interbeds of red, silty, and micaceous shale occur throughout the sandstone. At Mt Charlotte No. 1 (loc. 13) on the southeastern margin of the basin, a basal 19 m conglomerate bed is present. Slumping and evidence of contemporaneous deformation with deposition is present at the same locality.

Age

Fossils are rare, but Cruziana and other trace fossils (Wells et al. 1970 p.81) suggest that the formation is Ordovician (late Caradocian or Ashgillian). An asphid trilobita pygidium was noticed in the top part of core 3 (1369 ft BRT) in Mt Charlotte No 1 (see Appendix I).

Petrography

The arenites are both mineralogically (subgreywacke) and texturally (moderate sorting, subangular grains) submature. They range from very fine to medium-grained (Appendix 1). Euhedral tourmaline grains indicate closeness of source area in the south. Iron rich and kaolinitic (?) cements are common.

Isopach and Lithofacies

The restored isopach and lithofacies map of the Carmichael Sandstone (Fig. 17) shows a blanket type deposit over most of the basin. There is a marked thickening of the formation in the southeastern corner to over 200 m. This thickening is suggested by the lithological correlation between Erlunda No. 1, Mt Charlotte No. 1 and McDills No. 1 (not in the basin, latitude: 25°43'50" longitude: 135°47'25") where in the last mentioned well it is 341 m thick.

The lithofacies data are included in Table 18.

Environment of Deposition

The presence of Cruziana and the abundance of ripple marks and cross-beds suggest a shallow to very shallow marine environment and the halite pseudomorphs indicate high salinity. Some of the arenites are immature, and the environment was not vigorous enough for the sorting and rounding of the sediments to keep pace with the rate of deposition in a low-energy estuary or delta (Wells et al. 1970).

The Carmichael Sandstone shows both shallow-marine and continental characteristics, and the most likely environment of deposition thus indicated is an estuary or delta in the south, with shallow marine conditions in the north.

Slumping and evidence of penecontemporaneous deformation indicate that the Rodingan Movement which brought the Larapinta Group sedimentation to a close may have already commenced during Carmichael deposition in the south.

RESTORED ISOPACH & LITHOFACIES MAP
CARMICHAEL SANDSTONE – AMADEUS BASIN
0
50
100 km
Well locality
Thickness (metres)
Outcrop locality
Thickness (metres)
25 Isopach interval 25 metres
LITHOFACIES INDEX
50% shale 50% sandstone
To accompany Record
Author: L.E. Kurylowicz
Date: February 1975
Fig. 17
128°00'
129°00'
130°00'
131°00'
132°00'
133°00'
134°00'
135°00'
136°00'
23°00'
24°00'
25°00'
26°00'

Table 18. Carmichael Sandstone Lithofacies

Locality No.	% Sand	% Shale	% Carbonate	% Exposed
3	80	20		
4	65	35		
5	74	26		
6	80	20		
7	47	53		
8	33	67		
12	53	47		
13	52	48		
14	75	25		
18	43	57		
19	44	56		
20	30	70		
21	22	78		
23	80	20		
24	72	28		
25	74	26		
42	63	37		100
47	60	34		94
48	40			40
50	55	15		70
59	85			85
70	80			94
83	85			85

SUMMARY

Thick orthoquartzite (over 900 m thick) of the Pacoota Sandstone replaced the carbonate sediments of the Pertaoorrta Group with no major change in depositional limits. The topography of the land area on the margins of the basin was probably elevated, especially in the west.

The lower part of the Pacoota Sandstone represents a period of redistribution of dune sands by river systems from the west and from the south. Simultaneously, sediments were deposited in a broad, shallow sea with submarine sand flats and low longshore bars. All the sands were above wave base thus affording opportunities for reworking and gradual build up of blanket type sand body.

Conditions became more quiet during deposition of the upper part of the Pacoota. A sequence of increasingly extensive transgressions and decreasingly extensive regressions was established. The cleaner sandstones become thinner, more numerous, and finer-grained upwards, and the intervening sections become more shaley. This suggests that during subsidence the shoreline became generally more distant from the depocentre of the basin. Also the water depths became concomitantly greater, and there was decreased sediment response to transgression and regression.

The abundance of supermature orthoquartzizites and the almost complete absence of feldspar in the arenites of the Pacoota Sandstone suggest either tropical weathering or a predominantly sedimentary source area. Bimodality, in places, suggests mixing of provenances.

The palaeolatitude data of Irving (1964) suggest that during the Ordovician, the Amadeus Basin may have been approximately at latitude 15°N., and that there was a drift to the north during Larapinta Group time. The climate may have become more arid.

During Horn Valley Siltstone deposition the sea bottom was below wave base. Anaerobic conditions developed in the deep bottom water, and the main sediments, deposited were black carbonaceous lutites. Aerobic conditions prevailed in the upper water, as evidenced by the prolific fauna. Over 400 m of sediments were deposited with an increasing proportion of calcareous sediments towards the margin of the basin where wave and winnowing action was stronger.

Predominantly sandy sediments (up to 163 m thick) were again deposited during the lower Stairway Sandstone time. A vigorous, above wave base environment developed as a result of regression and shallowing of the sea. There may have also been a corresponding increase in coarser-grained quartz grains. During Stairway Sandstone time the predominant current direction was from the southeast. (Wells et al. 1970).

The lutaceous and chemical sediments (phosphorites and carbonates) of the middle Stairway Sandstone (up to 207 m thick) were deposited in a low energy, strongly reducing environment.

The upper Stairway Sandstone (up to 291 m thick) represents a major transgressive phase of deposition over a peneplaned hinterland to the south. As a result of the transgression and deepening of the sea, a large transgressive body of sand (barrier island or beach) was deposited over the area. The incoming of large amounts of euhedral, fresh as well as strongly kaolinized subrounded potassium feldspar grains indicate a nearly plutonic source area, and a sedimentary source area under arid conditions.

The lutites of the Stokes Siltstone (over 600 m thick) were deposited in a very broad, shallow and quiet sea. Salinity became greater by evaporation under arid conditions and ultimately anhydrite, gypsum, and halite were precipitated.

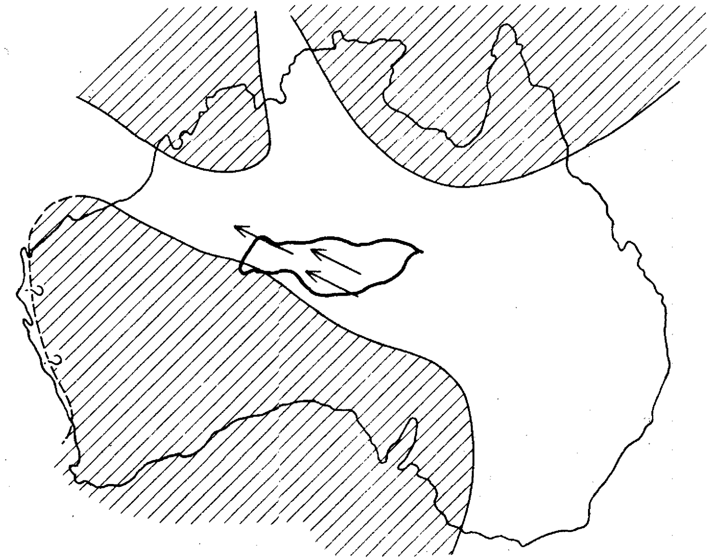
Deltaic or estuarine sediments of the Carmichael Sandstone (over 100 m thick) were deposited over a less extensive area of the basin than the underlying Stokes Siltstone. This regressive body of sand (or subgreywacke type) brought the marine sedimentation in the Amadeus Basin to a close. Some evidence of penecontemporaneous deformation exists in the southern part of the basin.

The total isopach map of the Larapinta Group is presented in Fig. 18.

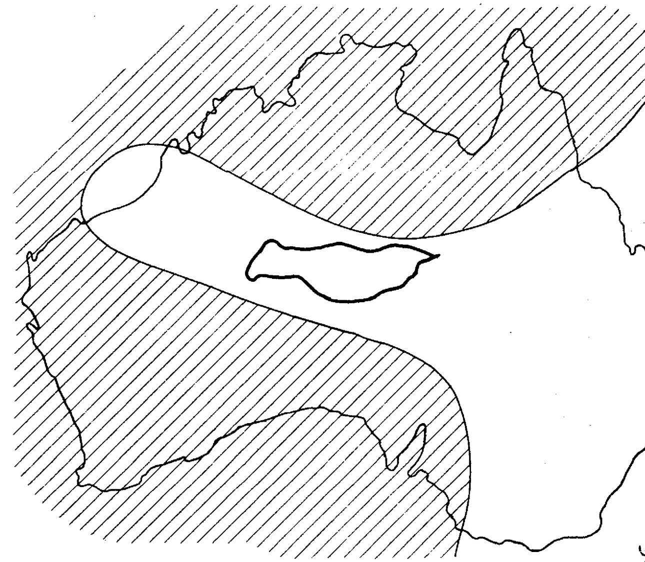
Palaeogeographic maps from Pacoota Sandstone time to Carmichael Sandstone time and cross-sections showing history of sedimentation of Larapinta Group (after Wells et al. 1970) are presented in Figs. 19 and 20.


RESTORED ISOPACH MAP
TOTAL LARAPINTA GROUP - AMADEUS BASIN
0
50
100 km
23 Well locality
1173 Thickness (metres)
75 Outcrop locality
739+ Thickness (metres)
—100— Isopach, interval 100 metres
To accompany Record
Author: L.E. Kurylowicz
Date: February 1975
Fig. 18

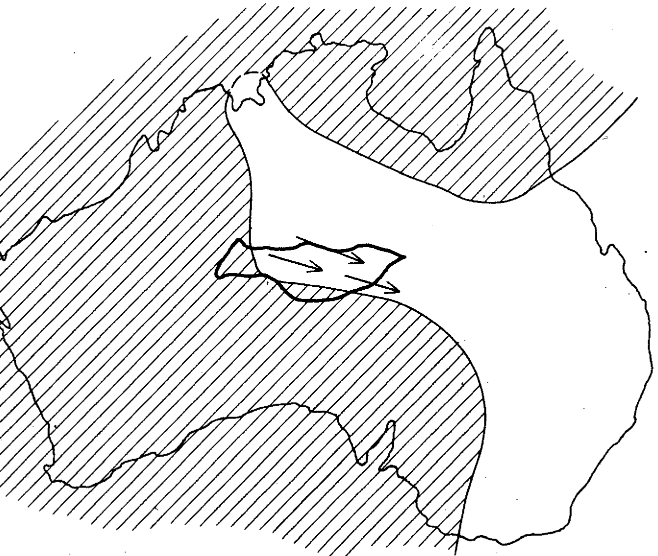
(d) Lower Stairway Sandstone time (Arenigian - Llanvirnian)



(e) Upper Stairway Sandstone and Stokes Siltstone times (Llandeilian - Caradocian)



(f) Carmichael Sandstone time (Ashgillian?)

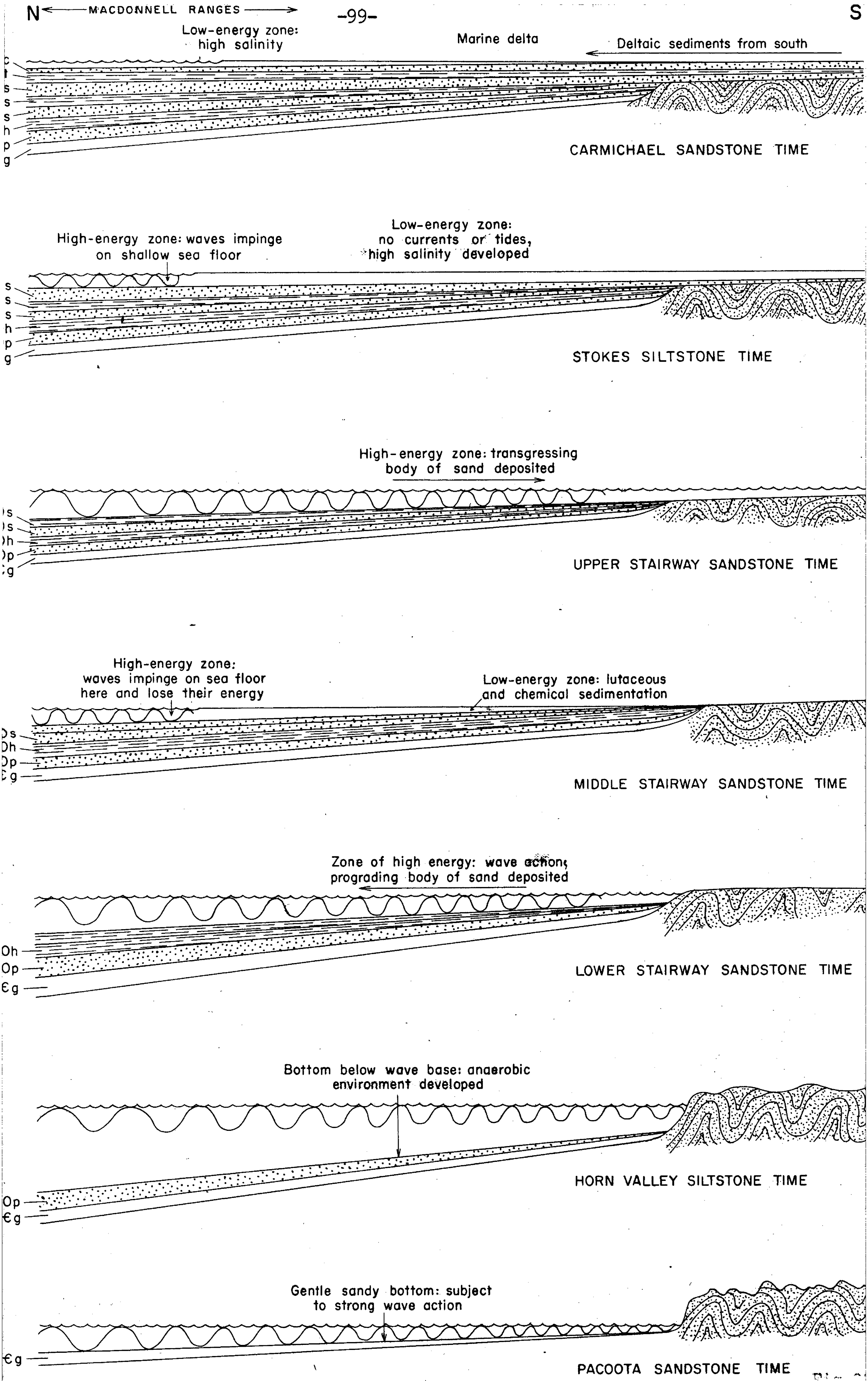


(a) Pacoota Sandstone I time (Trempealeauan)

(b) Pacoota Sandstone II and III times (Tremadocian - Arenigian)

(c) Horn Valley Siltstone time (Arenigian)

Fig. 19



sections showing history of sedimentation of Larapinta Group (Wells et al.

7. POROSITY STUDY

Introduction

Porosity is an essential element of petroleum reservoir rock. It is a measure of the void space expressed as a percentage of the bulk volume of the rock. The total volume of connected and unconnected voids thus expressed is the absolute porosity. The effective porosity, also expressed as a percentage of the total reservoir rock volume, is an important factor in the migration, accumulation, and storage of petroleum (Levorsen, 1967, p. 101), and as such is of particular significance in studies of reservoir engineering.

There is a wide variation among reservoir rocks in the size of the individual pores and in the arrangement of the pores with respect to one another. These variations are primary if they are controlled by the original depositional framework or fabric of the rock. The variations are secondary where they are the result of subsequent post-depositional factors i.e. fracturing and shattering, solution, redeposition, cementation, and compaction.

The pore pattern comprises the pore size and shape, the nature of pore connections, the character of the pore walls, and the distribution and number of larger pores and their relations to one another. The sizes of individual pores ranges from subcapillary and submicroscopic openings through capillary-sized openings to solution cavities of all shapes and sizes, including caverns formed in carbonate rocks. The individual pore may be tabular, or it may be rounded; or it may be a thin, intercrystalline, tabular opening that is 50-100 or more times larger in one direction than in another. The pore walls may be clean or coated with clay-mineral particles, platy accessory minerals, or rock fragments. The tortuosity of the pore pattern is the ratio of the distance between two points, by way of the connected pores, to the straight-line distance. Pinpoint porosity consists of minute, isolated pores visible under the binocular microscope (Levorsen, 1967).

The pore pattern of a clastic reservoir rock is a function of several petrographic characteristics. These include grains - sizes, shapes, sorting, chemical and mineral composition, matrix (amounts of each minerals, how distributed, mineral and chemical composition) and cement (character, composition, amount, distribution with respect to grains and matrix).

Quantitative Porosity Determination

The porosities of the three sandstone formations of the Larapinta Group in the Amadeus Basin were determined in twenty four wells by firstly examining all the available core analysis data (Appendix II). Next, the porosities were obtained from the acoustic velocity or sonic log, the micro-resistivity devices (FoRxo, microlog), and caliper log. The porosity logs were calibrated against the core porosities wherever available. Only one well, Palm Valley No. 3, had a complete suite of logs (including density and neutron) to enable the differentiation of fracture porosity and intergranular porosity (Appendix II).

Sonic or Acoustic Velocity Log

The sonic log is a recording depth versus the time Δt required for a compressional sound wave to traverse one foot of formation. The interval transit time Δt is the reciprocal of the velocity of the compressional sound wave.

In sedimentary formations the velocity of sound depends principally on the density of the rock matrix (equivalent to the petrographic term 'framework') and on porosity distribution. After numerous laboratory determination, Wyllie et al. (1958) concluded that in clean and consolidated formations with uniformly distributed small pores there is a linear relationship between porosity and transit time.

$$\Delta t_{log} = \phi \Delta t \text{ fluid} + (1 - \phi) \Delta t \text{ matrix}$$

$$\text{or } \phi = \frac{\Delta t \text{ log} - \Delta \text{tma}}{\Delta t \text{ f} - \Delta \text{tma}}$$

where- Δt log = reading on the sonic log in microseconds/feet

Δt ma = matrix material transit time

Δt f = formation fluid transit time (about 189 microseconds/feet)

Microresistivity Devices

Microresistivity devices are used to measure Rxo (resistivity of the flushed zone) and to delineate permeable beds by detecting the presence of mud cake. Very close to the hole all the formation water and some of the hydrocarbons, if present, are flushed away by the mud filtrate. The resistivity, Rxo, of this flushed zone is expressed by the Archie formula (Schlumberger, 1972).

$$Rxo = \frac{FRmf}{Sxo^2}$$

Where Rmf is the resistivity of the mud filtrate, Sxo is the mud filtrate saturation, and F is the formation resistivity factor which is also related to porosity by another Archie formula.

$$F = \frac{a}{\phi^m}$$

where m is the cementation factor and 'a' is a constant determined empirically.

Caliper Log

The caliper log measures a continuous record of the diameter of a hole. It is used mainly to check reliability of other wireline logs. The microcaliper log is used to detect the existence of a mud cake which qualitatively only indicates porous zones.

Porosity Distribution in the Larapinta Group

Areally

The results of the quantitive log evaluation (Appendix II) are summarized in Table 18.

Porosity distribution maps (Figs. 21-28) were drawn for the four units of the Pacoota Sandstone and two members of the Stairway Sandstone; but the lack of suitable data precluded the drawing of a porosity map for the Carmichael Sandstone. Average porosity as well as the porosity - metre values were determined at each well. The porosity - metre concept is used to facilitate hydrocarbon reserve calculations. For example, ten metres of sandstone with a uniform 10% porosity throughout would equal one porosity - metre of void space. The individual porosity distribution maps are discussed below:

Pacoota Sandstone - P4 (Fig. 21)

The average porosity of the P4 unit (lower Pacoota Sandstone) varies from zero in the Palm Valley and Orange area to 4% in the east at Alice No. 1 (loc. 1), and through 6 to 10% southwards in the Mereenie area. The distribution is only tentative because of the small number (9) of wells from which quantitative data could be obtained. East Mereenie No. 1 has the greatest pore volume (2.58 porosity - metres) for the P4 unit in the basin.

Pacoota Sandstone - P3 (Fig. 22)

Better reservoir conditions (both in average porosity and total pore space) are present in unit P3. The average porosity varies from about 4% in the Palm Valley area in the north to over 12% to the southeast and to the southwest. Similarly the total pore volume increases from 0.07 porosity metre in Palm Valley No. 3 to 5.14 porosity-metres in Alice No. 1 (loc. 1) and 4.37 porosity-metres, in the East Mereenie No. 2 (loc. 4). There is, therefore, a significant southward trend of increasing porosity in the P3 unit.

Locality No	Well Name	Carmichael Sandstone		Stairway Sandstone								Pacoota Sandstone									
				Upper		Middle		Lower		Total		P1		P2		P3		P4		Total	
		%	%xh	%	%xh	%	%xh	%	%xh	%	%xh	%	%xh	%	%xh	%	%xh	%	%xh	%	%xh
	Alice 1	-	-							-	-	15.8	9.44	12.0	2.05	12.3	5.14	4.3	1.23	12.1	17.86
	East Johnny's Creek 1													?5.8							
	East Mereenie 1	11.7	8.31	8.3	1.54	?	?x1.22	8.2	1.15	8.2	2.69*	9.8	2.81	7.0	0.09	9.8	3.32	9.1	2.58	9.5	8.80
	East Mereenie 2	?	?	8.9	0.62	10.3	4.90	7.1	0.24	10.0	5.76	5.9	1.87	6.6	0.89	10.1	4.37	8.8	0.94	8.1	8.07
	East Mereenie 3	14.9	?16.03	8.6	1.83	16.8	?7.94	7.5	1.14	11.5	9.64	5.6	1.02*								
	East Mereenie 4	?	?	4.0	0.10	12.0	0.44	8.6	1.00	8.6	1.54	6.5	0.40	0	0	11.6	3.65	8.8	0.94	10.4	5.19
	Erlunda 1	11.0	3.59							-	-									-	-
	Gosses Bluff 1									6.5	?2.58										
	Mereenie 1									8.2	?	6.9	?								
	Mt. Charlotte 1	11.3	5.92																		
	North Mereenie 1	?	?	9.5	0.38	0		9.5	0.38	9.5	0.76	0		0		6.0	0.13*				
	Orange 1	-	-							6.1	5.50	8.6	4.06	11.0	4.02?	7.3	?3.12	0		8.9	?11.20

h = net pay in metres.

Table 19 cont. Summary of Porosity Results - Larapinta Group, Amadous Basin

Locality No	Well Name	Carmichael Sandstone		Stairway Sandstone								Pacoota Sandstone									
				Upper		Middle		Lower		Total		P1		P2		P3		P4		Total	
		%	%xh	%	%xh	%	%xh	%	%xh	%	%xh	%	%xh	%	%xh	%	%xh	%	%xh	%	%xh
18	Palm Valley 1	5.2	2.06	3.5	0.91	4.0	1.40	4.2	4.35	4.1	6.66	4.0	0.50	4.5	0.22	3.8	0.46	0		4.0	1.18
19	Palm Valley 2	5.2	1.13	4.0	1.04	5.4	1.61	?6.2	3.70	?5.5	6.35									?8.0	
20	Palm Valley 3											4.9	0.70	4.9	0.09	3.1	0.07	0		4.7	0.86
21 ?	Tyler 1	15.6	1.47							5.5	4.12										
23	West Mereenie 1	?	?	9.4	3.76	8.5	0.26	?8.0	1.12	?8.7	5.14	10.7	2.15	7.0	0.34	12.4	2.80	10.0	1.80	10.8	7.09
24	West Mereenie 2	?	?	10.5	0.86	?	?	6.8	1.04	?8.1	1.90	7.3	0.73	0		7.2	2.63	6.6	2.25	7.0	5.61
25 ?	West Waterhouse	5.0	1.37	6.5	0.63	4.9	0.49	3.6	1.40	4.3	2.52	8.0	0.93	7.9	1.95	7.1	0.82			7.7	3.70+
26	AP1			15.3	6.11	0		8.0	4.78	10.9	10.89	11.7								11.7	?
27	AP2			11.7	2.35+	14.0	1.88	10.7	6.33	11.4	10.56-										
28	AP3			11.4	3.30	12.7	4.72	9.3	7.40	11.1	16.20										
29	AP4			16.6	7.30	-		-		16.6	7.30										

Pacoota Sandstone - P2 (Fig. 23)

The average porosity distribution of unit P2 is similar to that of the underlying unit P3. However, although the average values of porosity are slightly greater (e.g. 4.5% at Palm Valley), the total pore space is less for unit P2 than for the underlying unit P3.

Pacoota Sandstone - P1 (Fig. 24)

The average porosity distribution of unit P1 is similar to that of the underlying units. However, both the average values of porosity and total pore space are larger than for the underlying units. The average porosity varies from 4.0% in Palm Valley No. 1 (loc. 18) to 11.7% in AP1 (loc. 26) to the southwest, and to 15.8% in Alice No. 1 (loc. 1) to the east. The pore space correspondingly varies from 0.50 porosity - metre in Palm Valley No. 1 to 9.44 porosity - metres in Alice No. 1. Unit P1 represents the best reservoir of the total Pacoota Sandstone.

Total Pacoota Sandstone (Fig. 25)

The total Pacoota Sandstone has a porosity distribution similar to that of the uppermost P1 unit. Total pore space varies from 0.86 porosity - metre at Palm Valley No. 3 (loc. 20) to 8.80 porosity - metres in East Mereenie No. 1 (loc. 3), and to 17.86 porosity - metres in Alice No. 1 (loc. 1).

Lower Stairway Sandstone (Fig. 26)

The lower member of the Stairway Sandstone has a southerly increasing porosity trend. The average porosity varies from a low of 3.6 in West Waterhouse No. 1 (loc. 25) to a maximum of 10.7% in the BMR AP2 (loc. 27). The total pore space varies from 0.24 porosity - metres at East Mereenie No. 2 (loc. 4) to a high of 7.40 porosity - metres at AP3 (loc. 28).

Upper Stairway Sandstone (Fig. 27)

The average porosity distribution of the transgressive upper


Fig.21
POROSITY DISTRIBUTION
PACOOTA SANDSTONE-P4 (lower)
AMADEUS BASIN
Measured outcrop location
Well locality
Average porosity
Average porosity x Net porous thickness (metres)
Average porosity
100 km
Record
AUS 1/352

Fig. 22 POROSITY DISTRIBUTION PACOOTA SANDSTONE-P3 AMADEUS BASIN

Fig. 23
POROSITY DISTRIBUTION
PACOOTA SANDSTONE-P2
AMADEUS BASIN
Measured outcrop location
Well locality
Average porosity
Average porosity x Net porous thickness (metres)
Average porosity
0
50
100 km
Record
AUS 1/351

Fig.24 POROSITY DISTRIBUTION PACOOTA SANDSTONE–P1 AMADEUS BASIN

Fig. 25 POROSITY DISTRIBUTION TOTAL PACOOTA SANDSTONE AMADEUS BASIN

Fig. 26 POROSITY DISTRIBUTION
STAIRWAY SANDSTONE (lower)
AMADEUS BASIN


Fig. 27
POROSITY DISTRIBUTION
STAIRWAY SANDSTONE (upper)
AMADEUS BASIN
Measured outcrop location
Well locality
Average porosity
Average porosity x Net porous thickness (metres)
Average porosity
0
50
100 km
Record
AUS 1/356


Fig 28
POROSITY DISTRIBUTION
TOTAL STAIRWAY SANDSTONE
AMADEUS BASIN
Measured outcrop location
Well locality
Average porosity
Average porosity x Net porous thickness (metres)
Average porosity
0 50 100km
AUS 1/350

Stairway Sandstone unit is similar to that within the lower Stairway Sandstone member (i.e. increasing to the south). A low of 4% porosity is shared by Palm Valley No. 2 (loc. 19) and East Mereenie No. 4 (loc. 6). The average porosity of 16.6% for AP4 (loc. 29) is the highest for any member of the Larapinta Group in the basin. Total pore space varies from 0.1 porosity - metres at East Mereenie No. 4 to 7.30 porosity - metres at AP4.

Total Stairway Sandstone (Fig. 28)

The total pore space distribution of the whole Stairway Sandstone differs from the distribution within the upper Stairway Sandstone unit in that there is some pore volume contribution from the middle member in the Mereenie area. The total pore space varies from 0.76 porosity - metres at Northwest Mereenie No. 1 (loc. 24) to a high of 16.20 at AP3 (loc. 28).

CONCLUSIONS

All the arenite members of the Larapinta Group (Pacoota Sandstone and Stairway Sandstone) have an increasingly southward porosity distribution. In general, the total porosity distribution is similar to the average porosity distribution.

Also, there is a decrease of average porosity with increasing depth in most of the wells that were studied.

In the study of the Palm Valley Field it became apparent that the log indicated pore space (in the order of 4 percent) which was not visible under the petrographic microscope (Appendices I and II). Therefore, it is recommended that in the detailed study of tight formation rocks, the scanning electron microscope be used to identify the nature of the contributory pore space. A scanning electron microscope study, carried out by Kieke & Hastmann (1974) on carbonate rocks from Texas, resulting in the detection of microporosity.

Causes of Porosity Variations

Pacoota Sandstone and Stairway Sandstone

Petrographic (Appendix I) and petrophysical (Appendix II) studies indicate that fracture porosity is predominant in the north (Palm Valley area), whereas intergranular porosity is prominent to the east in Alice No. 1 (loc. 1) and in the Mereenie field area to the west.

The main causes of porosity variation in decreasing order of importance are -

- growth of authigenic silica
- pressure welding (particularly in the finer-grained ortho-quartzites)
- suturing and interpenetration of grains
- rare carbonate cement
- rare phosphate cement
- rare anhydrite cement
- rare argillaceous matrix
- rare pyrite cement.

The factors which most influenced the porosity variation include:-

1) Proximity to the basin's northern margin i.e. the porosity decreases systematically for all units from north to south. The main time of silicification is believed to be associated with the Alice Springs Orogeny.

2) Porosity decreases with increasing overburden thickness (Table 19). The overburden pressure probably assisted the solution of silica in the northern part of the basin. In the east (Alice Area) erosion during the Rodingan movement resulted in the removal of the post - Pacoota Sandstone sediments. Accordingly, there was less overburden in the area, resulting in the preservation of much of the original void space.

Group or Formation	Parameter	Mereenie Area	Tyler Area	Palm Valley Area	Alice Area	AP4 Area
Pertinjara Group	Total Thickness metres (feet)	=1830 (6004)	2740 (8989)	3658 (12,000)	3658 (12,000)	1000 (3280)
	Cumulative Thickness on top of Pacoota metres (feet)	=3140(10,302)	4978 (16,332)	5117 (16,789)	3948 (12,953)	1600 (5249
Mereenie Sst	Total Thickness metres (feet)	= 540 (1772)	838 (2749)	621 (2037)	290 (951)	100 (328)
	Cumulative Thickness on top of Pacoota metres (feet)	=1310 (4298)	2238 (7342)	1459 (4787)	290 (951)	600 (1968)
Carmichael Sst) Stokes Slt) Stairway Sst) Horn Valley Slt)	Total Thickness metres (feet)	= 770 (2526)	1400 (4593)	838 (2749)	eroded	500 (1640)
"	Cumulative Thickness on top of Pacoota Metres (feet)	= 770 (2526)	1400 (4593)	838 (2749)	0	500 (1640) *

* Pacoota Sandstone Absent.

3) There is some correlation in the Pacoota Sandstone between the increase in average grain size (from Palm Valley to Mereenie) and the improved porosity development.

4) Generally, the sandstone facies becomes prominent in the southern portion of the basin so that more reservoir volume is available, even though the total sediments thickness decreses to the south.

5) Surface fracture studies (Geophoto Services, 1973) and a wireline log analysis (Appendix II) indicate that fractures are vertical. These fractures are interpreted to be mainly tensional features associated with the folds. They occur either along the crestal portion or, to a greater extent, in the inflection zones along the flanks of the folds. This suggests that a north-south compression caused the main strain effects. The removal of overburden during the Rodingan movement was also a cause of fracturing; as sediments were unloaded through erosion, the upper parts expanded, and incipient weaknesses in the rocks became joints, fractures, and fissures. An increase of fracturing below an unconformity should, therefore, be expected. The unfilling of many of the fractures probably occurred during Pertnjara Group deposition after the Alice Springs Orogeny.

8. HYDROCARBON PROSPECTS OF THE LARAPINTA GROUP

General

Following Dr D.A. McNaughton's (1962) appraisal of the Amadeus Basin, five drilling prospects were delineated by surface geological mapping. Primary objectives to be drilled on each of the five closed anticlines were sandstones in the Gardiner, Arumbera and Areyonga Formations and fractured carbonate in the Bitter Springs Formation. All the above-mentioned formations are stratigraphically below the Larapinta Group. In addition, five prospects requiring geophysical work for the delineation of traps were nominated and indicated as the Waterhouse, Mereenie, Gosses Bluff, Palm Valley, and Carmichael Anticlines - most of them with targets in the Larapinta Group.

In assessing the remaining areas of the basin for possible hydrocarbon accumulations, the following factors have to be considered: the concentration and composition of organic matter in potential source rocks, the extent of abiogenic oxidation of the source sediments during and after deposition, the temperature and pressure and potential source rocks have been subjected to, the nature of the reservoir rock, the pore space and permeability, and the type of trap. Levorsen (1967, p.660) considers the trap to be the most important as it localizes both the depth and areal extent of the prospect.

Source Rocks

Analyses of sediments to determine whether they contain enough interstitial organic material to be source rocks for hydrocarbons have been performed since the early 1900's (e.g. Trask, 1932). However, it was not until the middle 50's that source rock analyses, in conjunction with geochemical maturation studies of crude oils, began to be used as a definitive exploration tool. In addition, extensive efforts have been made to correlate crude oils with their source rocks (e.g. pristane/phytane ratio study by

Powell & McKirdy in 1973). As the application of these techniques became more widespread, so methods of analysis were perfected.

These methods may be classified into three categories (Fletcher & Bay, 1975, p.5):

1. Visual analysis of particulate matter by microscope to determine the type and rank of organic matter.
2. Carbon isotopic measurements on the contained organic matter.
3. Quantitative determination of the ratio of organic carbon to total hydrocarbon content or total soluble organic matter.

A detailed geochemical evaluation of the Larapinta Group along these lines is presently being undertaken by Mr D.M. McKirdy as part of a Ph. D. thesis for the ANU. The tentative results of his work indicate that the Horn Valley Siltstone and middle member of the Stairway Sandstone may be considered good source rocks.

Unlike most source rocks for oil in Australia, the presumed source of the Mereenie oil (occurring in the Upper Cambrian to Lower Ordovician Pacoota Sandstone) is from marine organic matter (Powell & McKirdy, 1973; Table 1). The Mereenie type oil examplifies the concept that organic material originating from marine organisms (predominantly algae) is more easily converted to hydrocarbon, and generates greater quantities of hydrocarbon per unit weight of organic carbon, than terrigenous plant material (Phillipi, 1969). Furthermore, chemical reactions of the kind involved in hydrocarbon generation operate much more efficiently on finely disseminated marine organic matter (sapropel) than on more durable woody carbonaceous material swept in from terrigenous sources. However, it is still recognized that pollens, spores, and particles of terrestrial plants have contributed significantly to the source material of crude oil elsewhere in Australia.

The occurrence of crude oil in the Mereenie Anticline demonstrates that favourable source material (shale and carbonate in the Horn Valley Siltstone, and shale in the middle part of the Stairway Sandstone) and preservation conditions existed during the Lower Ordovician in the Amadeus Basin. During Horn Valley Siltstone deposition, the upper waters were well aerated whereas strongly reducing, euxinic conditions, amicable to source material preservation were prevalent on the sea bottom. The middle unit of the Stairway Sandstone contains phosphorites (in which the dominant rock-forming mineral is collophane). Powell et al. (1975) state that the phosphorite - forming environment is also highly euxinic as reflected by the high nitrogen, sulphur, and oxygen content of the kerogen (insoluble organic matter) when compared with that from other sedimentary rocks. Also the high proportion of soluble organic matter in unaltered phosphorites suggest that oils derived from phosphatic source beds are capable of migration at an early stage of diagenesis.

Analyses by D.M. McKirdy (1975) indicate that the organic carbon content of the Horn Valley Siltstone ranges from 0.5% to 0.8% (based on three samples only). More encouraging, the total extract range is 600-1700 ppm. Organic carbon content in the Stairway Sandstone is 0.1 - 0.5% and the total extract of hydrocarbons is 80-440 ppm. Hunt and Meinert (1954) after comparing rocks close to oil fields with those where no oil field are present concluded that if fine-grained rocks contained more than 130 ppm hydrocarbons then they were good source rocks. Organic content of shales should be at least 0.5% (Ronov, 1958) and that in carbonates should be at least 0.2% (Gehman, 1962) to have been good source rocks.

The hydrocarbon-generation potential of a sedimentary basin is defined as the ability of sediments within the basin to generate oil (Conybeare, 1965, p.509). The hydrocarbon-yield capacity of a sedimentary basin is defined as the ability of the hydrocarbons generated within a basin to become entrapped as accumulations.

The following assumptions were made in estimating the oil-yield capacity of the Horn Valley Siltstone (after method II of Conybeare's estimate of the hydrocarbon-generation potential of the Evergreen Shale in the Surat Basin):

1. Effective area of the Horn Valley Siltstone (area within which the top of the Horn Valley Siltstone was covered by at least 2,500 feet of sediments) - 10,000 sq. mi, average thickness is taken as 100 metres (about 300 feet).

2. Present organic content of the Horn Valley Siltstone, based on only 3 analyses by McKirdy (1975) - 0.65 percent by weight. Systematic sampling and analyses of the Horn Valley Siltstone may increase this figure.

3. Maximum amount of present organic matter in Horn Valley Siltstone in the form of hydrocarbons, based on analyses of other shales (Philippi, 1956) - 2% by weight.

4. Ratio of oil possibly generated in the Horn Valley Silstone to oil accumulated in traps; this is the oil-generation potential to oil-yield capacity ratio. A ratio of 16:1 is used after Conybeare (1965 p. 523). This somewhat low figure is consistent with the large number of breached anticlines in the basin.

5. Average specific gravity of the Horn Valley Siltstone - 2.74 (Palm Valley No. 1 core analyses).

6. Barrels per short ton (2000 lbs)...........7

7. All the hydrocarbons generated are in the form of oil.

8. Estimates of oil reserves may be converted to estimates of gas reserves on the basis that one barrel of oil is equivalent to 960 cu. ft of gas at the surface ($V_2 = \frac{5.6154 \times 3000 \times 520}{14.73 \times 620} = 960$).

Method of Calculation

Effective area of Horn Valley Siltstone (1)....14 million acres (22,000 sq. mi).

Thickness.......................................300 ft

Volume (by planimetry).........................4300 million acre-ft

Total weight of effective volume (5)..........approx. 11,800 billion short tons

Weight of present organic matter in
Horn Valley Siltstone (2)....................77 billion short tons

Weight of hydrocarbons generated (3)...........1.5 billion short tons

Therefore the volume of hydrocarbons
generated (6).............................10.5 billion barrels

Oil-generation potential....................10.5 billion barrels

Oil-yield capacity (4)......................660 million barrels

The middle unit of the Stairway Sandstone (average 0.3% organic content) is estimated to have a smaller oil-yield capacity (about 400 million barrels) to that of the Horn Valley Siltstone. Assuming that the equivalent of 900 million barrels of oil (from both the Horn Valley and middle Stairway unit) is in the form of gas, it can be estimated that the volume of this gas when brought to the surface (assumption 8) amounts to about 860 billion cubic feet.

If the foregoing assumptions are correct, then it can be said that the Horn Valley Siltstone and middle unit of the Stairway Sandstone have yielded 260 (1160-900) million barrels of oil and about 860 billion cubic feet of natural gas. Thus most, if not all, of the oil and gas, which was generated in the above formations may have been discovered already in the basin. Therefore, shales within the upper part of the Pacoota Sandstone and the Stokes Siltstone should be examined as other possible source rocks before a final hydrocarbon-yield evaluation may be made.

Primary Migration and Hydrocarbon Generation

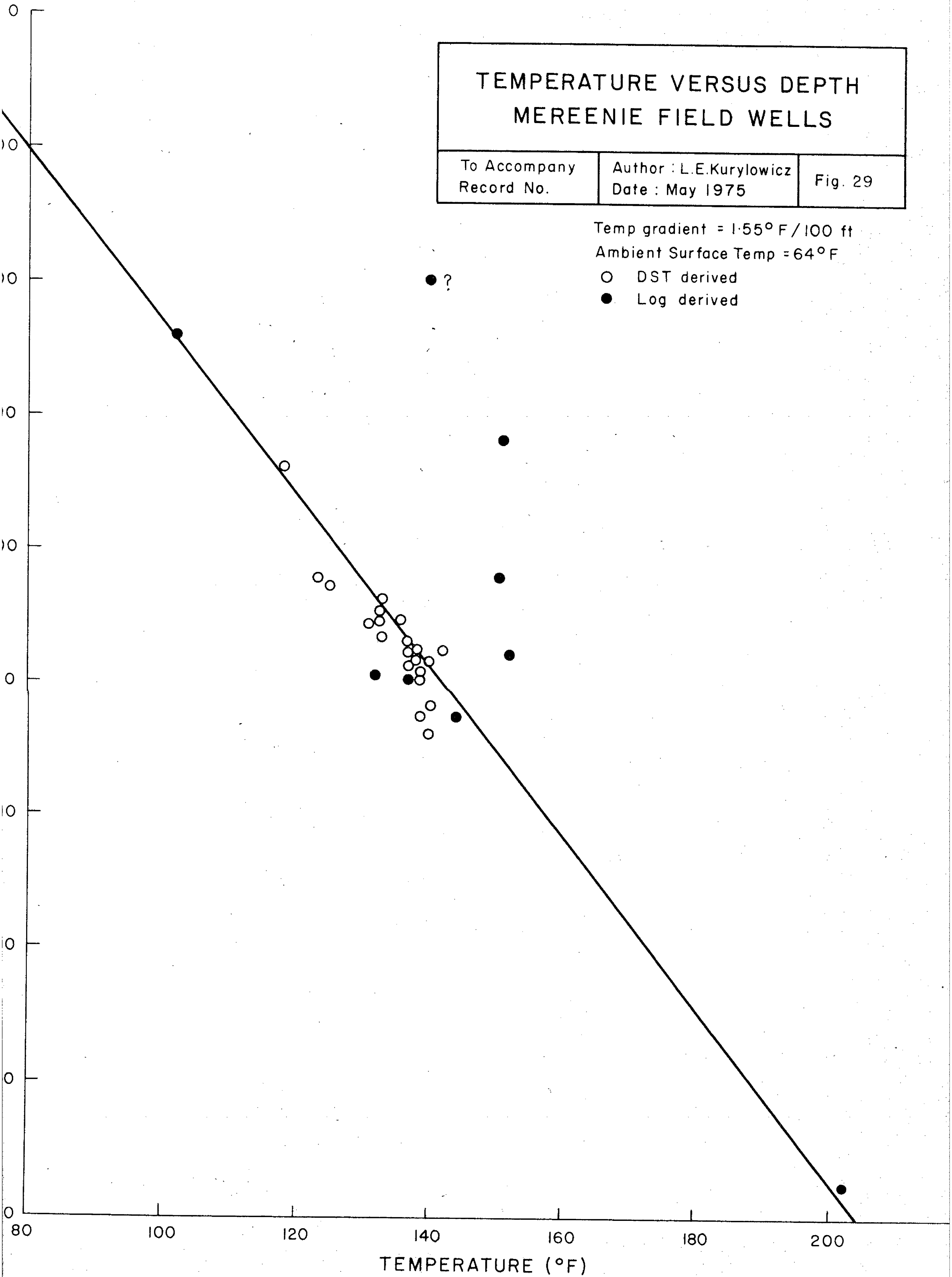
Much geological, geochemical, and experimental evidence leads to the interpretation that deep burial is necessary for oil origin and primary migration (R.J. Cordell, 1972). On the other hand, it has been concluded that primary migration may begin at 460-760 m (1500-2500 ft). Appreciable migration of Mereenie oil, derived from marine organic matter deposited in the Horn Valley Siltstone, is believed to have occurred during and after deposition of the Stokes Siltstone. In the depocentre of the basin, the Horn Valley Siltstone was succeeded by about 450 m of Stairway Sandstone and by 600 m of Stokes Siltstone, making a total of 1050 m (3445 ft) of overburden near Stokes Pass at the end of Stokes Siltstone time. The protopetroleum would have migrated updip (southwards) into the favourable reservoir rocks of the Pacoota Sandstone (downward expulsion of protopetroleum during compaction). The porosity distribution of the Pacoota Sandstone was probably the same as at present because of increasing sediment thickness to the north. However, the average intergranular porosity was probably much higher (about 30%) because of the absence of silicification which probably occurred during the Alice Springs orogeny (Carboniferous).

Organic content alone does not produce hydrocarbons. If present-day temperatures are historical maxima (a hypothesis supported by Fletcher & Bay, 1975, p. 23), then subsurface temperatures derived from wireline logs and DST data can be used to estimate the degree of thermal maturation. In the Mereenie Field wells, a temperature gradient of 1.55°F/100 ft was established (Table 21 & Fig. 29). The concomitant surface temperature was extrapolated at 64°F. Thus at the end of Stokes Siltstone time, the temperature of the Horn Valley Siltstone in the Stokes Pass area (presumed generative area) was about 117°F, assuming similar ambient surface temperature at that time. It is established in the literature that organic matter is not transformed into hydrocarbons until subsurface temperatures exceed 140°F or unless the reaction time has been very long. According to data presented by Hunt (1968), significant quantities of oil are generated between 180°F - 250°F, mostly gas is generated within the range of 250°F - 350°F, and from 350°F to 400°F degradation of liquid hydrocarbons begins so that only gas remains as the indigenous hydrocarbon.

Thus the significant conversion of protopetroleum into oil in the Mereenie Field is believed to have occurred within the reservoir rock (Pacoota Sandstone) during and after the deposition of the Pertnjara Group (cumulative thickness of sediments on top of Pacoota was 10,302 ft with an indicated temp. of 224°F).

Table 21 Summary of Temperatures in the Mereenie Field Wells

Well Name	Depth (ft BRT)	DST No. (if applicable)	DST Temp (^{o}F)	Log Temp (^{o}F)
Mereenie No. 1	3395	5	118	
	2406			104
East Mereenie No. 1	5433	17	132	
	4606	18	136	
	1920			140
	3170			152
	4181			151
	4711			156
East Mereenie No. 2	4182	1	126	
	4267	2	129	
	4309	3	129	
	4386	4	135	
	4441	5	136	
	4492	6	136	
	4646	7	137	
	4804	8	138	
	4804	9	140	
	4965	10	139	
	4992			132
East Mereenie No. 3	5215	4	139	
	4920	5	139	
East Mereenie No. 4	4761	6	142	
	5258			144
	8742			202
Northwest Mereenie No. 1	4840	1	137	
	4756	2	137	
	4950			137
West Mereenie No. 1	4562	1	139	
	4694	2	139	
	4755	3	138	
	4860	4	138	
	4959	5	140	
	5158	6	140	
	5399	7	140	
	5475			137
West Mereenie No. 2	4584	1	135	
	4994			136


TEMPERATURE VERSUS DEPTH
MEREENIE FIELD WELLS
To Accompany Record No.
Author : L.E.Kurylowicz
Date : May 1975
Fig. 29
Temp gradient = 1·55° F / 100 ft
Ambient Surface Temp = 64° F
DST derived
Log derived
?
80
100
120
140
160
180
200
TEMPERATURE (°F)

In the Palm Valley area, the cumulative thickness of sediments on top of the Pacoota Sandstone at end of Pertnjara Group deposition was 12,000 ft (Table 20). The temperature gradient of the Palm Valley well (Kurylowicz & Ozimic, 1975 (a)) is about 2.05°F/100 ft, assuming a similar surface temperature of 64°F to that of the Mereenie Field area. The palaeotemperature of the Pacoota probably reached 310°F (246° + 64°) at end of Pertnjara time. This may in part explain why only gas occurs in the Palm Valley area.

Reservoir Potential

The porosity study (Appendix II of this thesis and appendices I in Kurylowicz & Ozimic (1975a and b) indicate that the Pacoota Sandstone, and lower and upper members of the Stairway Sandstone are good reservoir rock (porosity greater than 4 percent), in the southern half of the basin of a line from Alice No. 1 in the east ot Gosse's Bluff in the west. North of this imaginary line, fracture porosity would provide the only reservoir storage left for hydrocarbons because of the increase in silicification towards the Macdonnel Ranges. Porosity values in the Pacoota Sandstone increase also to the east because of the fracturing caused by the inferred unloading of sediments during the Rodingan movement.

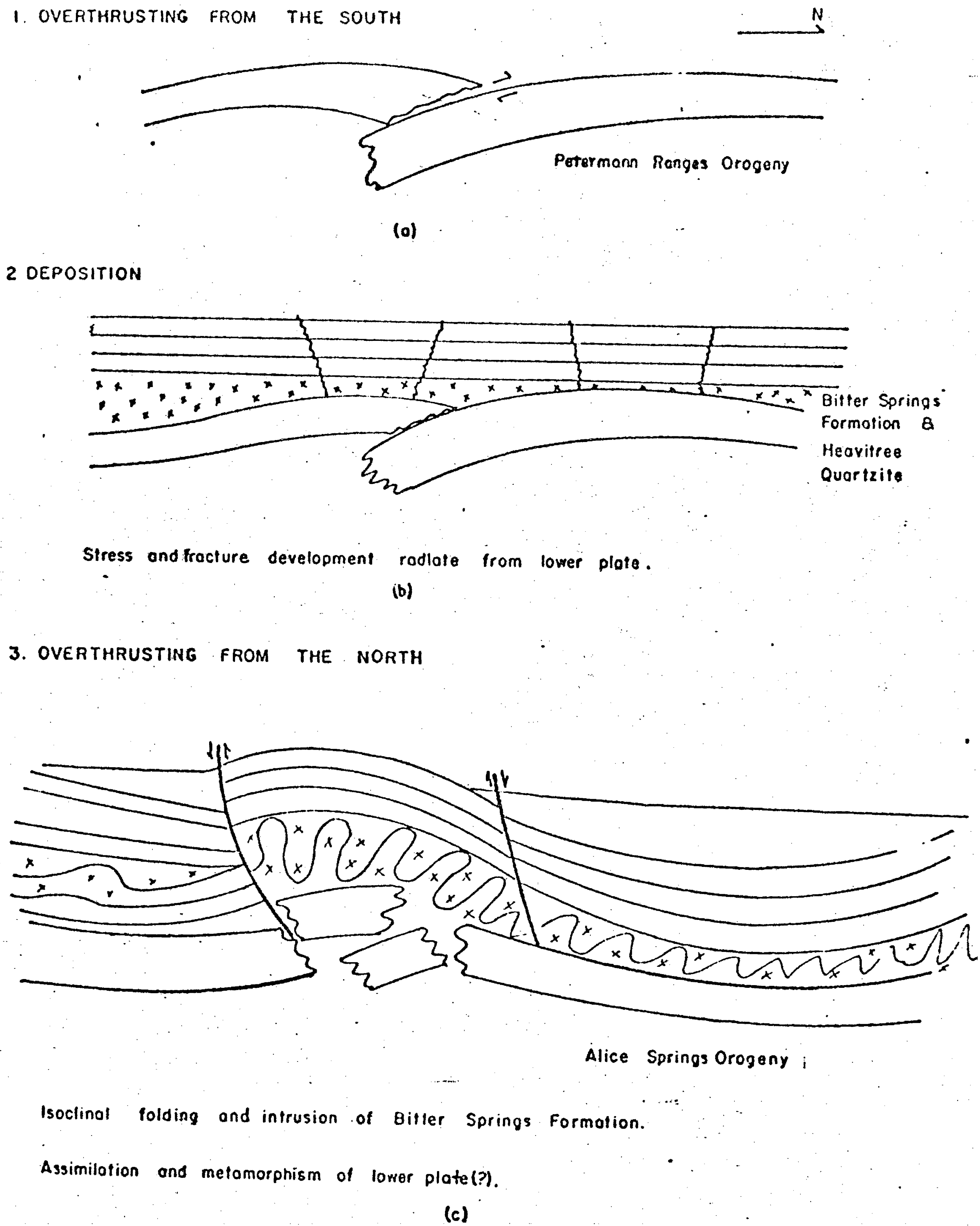
Traps

Remaining untested structural traps in the Amadeus Basin which contain favourable Larapinta Group sediments have been delineated by seismic surveys and are interpreted by Krieg (1974) and Mandrel Industries Inc (1974). Also, some stratigraphic traps are indicated from surface geology.

The traps are:

1. Mereenie Anticline Area (see Plate 7)

A simplified sequence of events for the development of the Mereenie Anticline was postulated by Mandrel Industries (1974, p. 32) from the results of the Central Amadeus Seismic survey and are shown in Fig. 30. The north-west-southeast thrusts and folds appear to have developed along linear



MEREENIE: POSTULATED DEVELOPMENT OF ANTICLINES

(After Mandrel Industries - 1974)

Fig. 30

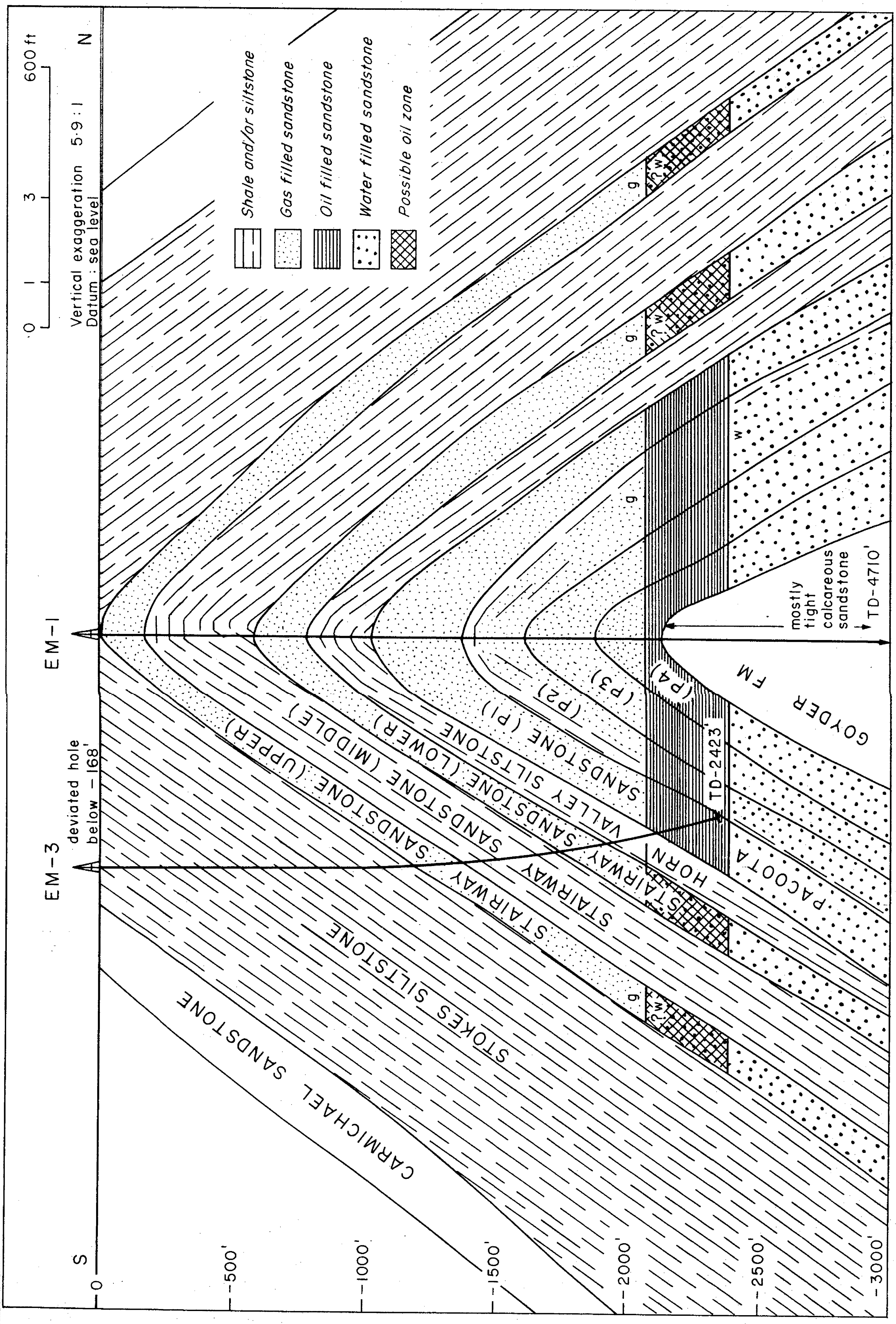
fracture planes originating in the lower plate (below the Bitter Springs Formation). Mandrel Industries (1974) state that two parallel northwest to southeast thrusts (Glen Edith Hill and Gardiner Range), intersect a third lineament oriented approximately east-west. The resulting faults, folds and intersection of these lineaments provide potential traps in the Pacoota and Stairway Sandstones. A fault with a large throw on the northern flank of the Mereenie Anticline (Mandrel Industries, 1974, p. 29) at least as far west as northwest Mereenie No. 1 is inferred from gravity data. The eastern existence of an extension of the fault is more demonstrable. This fault on the southern flank of Wild Eagle Syncline (between Mereenie and Gardiner Range Anticlines) provides for a structural trap of northwest dipping sediments (Larapinta Group Sediments) on the downthrown side of the fault (Plate 7, Prospect I).

2. A second trap along the Mereenie Anticlines (Plate 7, Prospect 2 and Fig. 31) is indicated in the lower and upper members of the Stairway Sandstone in the Mereenie Field (Kurylowicz & Ozimic, 1975 (b)). Possible oil zones occur beneath the gas zones. Thus two annulii of oil saturated sandstone may exist.

3. A triangular shaped fault block, at the intersection of northwest trending normal (down to the northeast) fault and the large east-west trending Deering thrust fault, provide for another possible trap within the Larapinta Group (Plate 7, Prospect 3).

4. Another triangular shaped fault block is formed by the intersection of the Deering thrust fault with a northwest trending normal (down to the south) fault, south of Gardiner Range Anticline in the Mt Solitary area (Mandrel Industries, 1974).

5. The Carmichael prospect is an east-west trending anticline, north of the Deering fault and about 30 km west of Gosses' Bluff. However, the porosity of the Pacoota Sandstone and Stairway Sandstone is low in this region because of the large overburden and nearness to the eroded northern margin of the basin (Plate 7, Prospect 5).



STRUCTURAL CROSS SECTION - MEREENIE FIELD

Author : L.E. Kurylowicz

Fig. 31

6. Dr D.A. McNaughton (pers. comm.) indicates that the area near the intersection of the extension of Palm Valley Anticline to the west and the Gardiner Range corresponds to an area of stratigraphic convergence. Thus a stratigraphic trap (porosity variation near the Gardiner Range) may exist in this area. A detailed porosity distribution study is required in this area (Plate 7, Prospect 6).

7. Krieg (1974) interprets a structurally higher area to exist 5-6 km eastward of West Waterhouse No. 1. Potential Reservoir traps exist in the Pacoota and Stairway Sandstones.

8. The north dipping, east-west trending Waterhouse Range thrust fault provides for two structural traps on the southern side of the fault (Krieg, 1974). The first is named the Southeast Waterhouse prospect and is located about 6 km east-southeast of Waterhouse No. 1 (Plate 7, Prospect 8). The second is located south of west end of Waterhouse Range surface expression and is formed by the arcuate trace of the Waterhouse thrust fault (about 6 km east-southeast of West Waterhouse No. 1).

9. Interpretation of seismic sections (Krieg, 1974) over the southwest plunging nose of the Ooraminna Anticline indicates marked thining of the Larapinta Group sediments from west to east over the anticline. The Stairway Sandstone may pinch out eastward where the geological map indicates Mereenie Sandstone lying directly on the Pacoota Sandstone. Porosity is good in this area because of unloading effects (Plate 7, Prospect 9).

10. The possibility of a stratigraphic trap exists in the Seymour range area where the Horn Valley Siltstone and Stairway Sandstone onlap the Pacoota Sandstone. Porosity should be very favourable (greater than 12%) in this region (Plate 7, Prospect 10).

CONCLUSIONS

The Horn Valley Siltstone and middle unit of the Stairway Sandstone are good source and cap rocks within the Larapinta group. Six hundred and sixty million barrels of oil equivalent (hydrocarbon) are estimated to have been yielded by the Horn Valley Siltstone alone. A total of 860 billion cubic feet of gas are estimated to have been yielded from the Horn Valley Siltstone and middle unit of the Stairway Sandstone. Thus most of the hydrocarbons that were generated may have been discovered. Additional source rock analyses are required on all the lutaceous and calcareous sediments within the Larapinta Group before a final hydrocarbon-yield evaluations may be made.

All the surface-delineated, unbreached, anticlines (containing Larapinta Group sediments) have been drilled. The remaining hydrocarbon traps (mostly fault blocks associated with anticlines) need seismic surveying to delineate potential traps. The dimensions (areal and vertical closures) of the remaining traps are smaller than either the Mereenie or Palm Valley Fields. The prospect of them being drilled depends upon economic factors. Stratigraphic traps may occur on the east (Ooraminna area), in the centre of the basin (Gardiner Range) and in the south (Seymour Range area) where stratigraphic convergence is noted.

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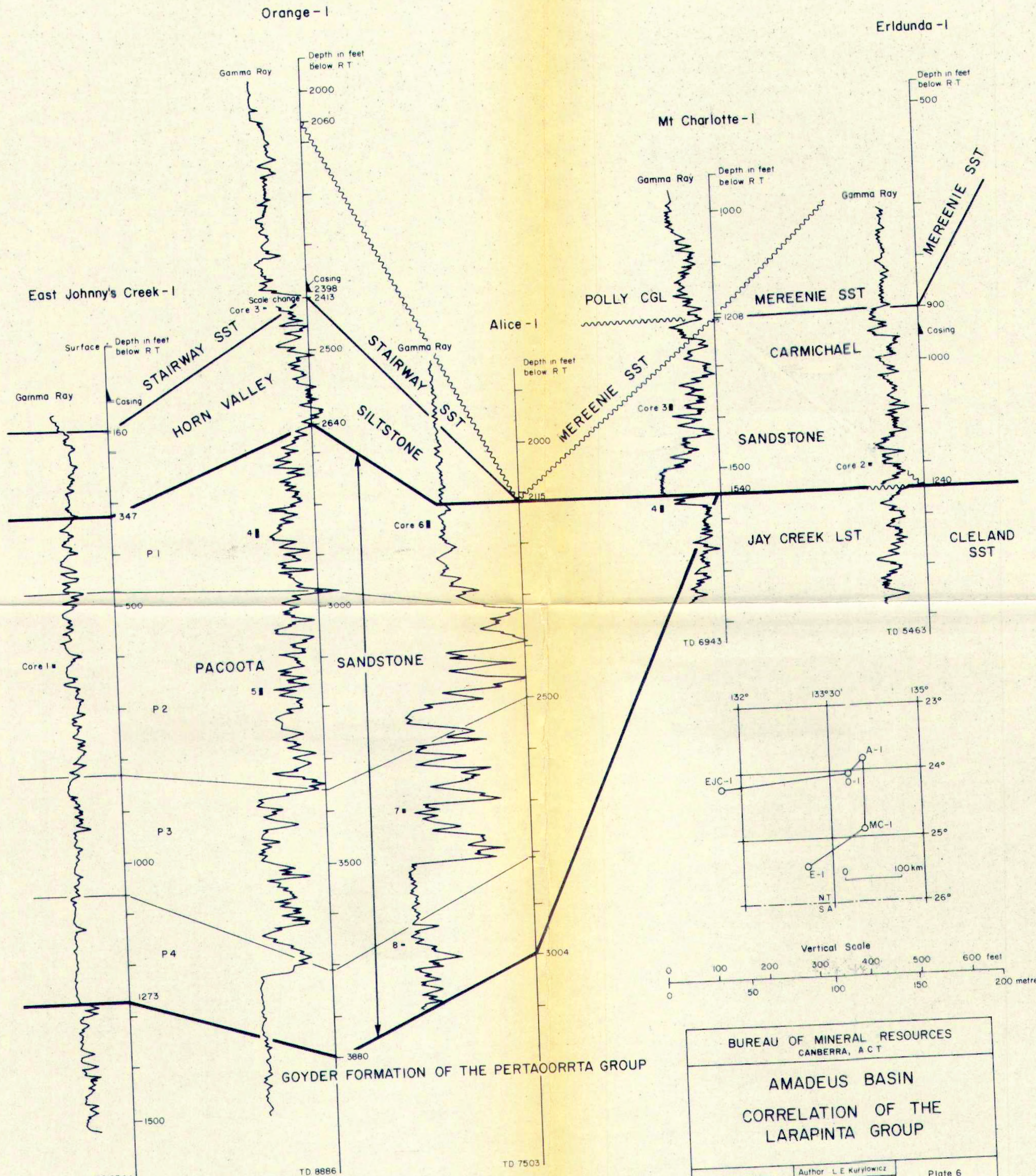
PETROLEUM PROSPECTS
AMADEUS BASIN
CENTRAL AUSTRALIA
Geology
(after Wells, A.T., Forman, D.J., Ranford, L.C. and Cook, P.J. 1970, Plate 42)
Plate 7
CANNING BASIN
GREAT ARTESIAN BASIN
WESTERN AUSTRALIA
NORTHERN TERRITORY
SOUTH AUSTRALIA
PETERMANN RANGES NAPPE - ROOT ZONE
STOKES PASS
ALICE SPRINGS
Hermannsburg Mission
Finke River
128° 00'
129° 00'
130° 00'
131° 00'
132° 00'
133° 00'
134° 00'
135° 00'
136° 00'
23° 00'
24° 00'
25° 00'
26° 00'
1
2
3
4
5
6
7
8
9
10
AGE
SYMBOL
ROCK UNITS
DIASTROPHIC EVENT
CAINOZOIC Cz
MESOZOIC M Rumbalara Shale De Souza Sandstone
PERMIAN Pzu Crown Point Formation Buck Formation Ligertwood Beds
CARBONIFEROUS
Alice Springs Orogeny
DEVONIAN Pzm Pertnjara Formation Finke Group
Pertnjara Movement
SILURIAN Mereenie Sandstone
Rodingan Movement
ORDOVICIAN CAMBRIAN Pzl Larapinta Group Pertaoorrta Group
Petermann Ranges Orogeny
UPPER PROTEROZOIC Pertatataka Formation Winnall Beds
Souths Range Movement
Areyonga Formation Inindia Beds Boord Formation
Areyonga Movement
Bitter Springs Formation Pinyinna Beds Heavitree Quartzite Dean Quartzite
Unnamed
YOUNGER PRECAMBRIAN Unnamed Bloods Range Beds Mount Harris Basalt
Unnamed
Unnamed
OLDER PRECAMBRIAN Olia Gneiss
Arunta Orogeny
Musgrave - Mann complex
Arunta Complex
Quartzite
INTRUSIVE IGNEOUS ROCKS
PRECAMBRIAN Granite
REFERENCE
Geological boundary, position approximate
Unconformity
Anticline, showing plunge
Syncline, showing plunge
Overturned anticline
Overturned syncline
Axial trace
Fault
Fault, showing dip of thrust plane, where approximate, line is broken; where inferred, queried
Well locality
Measured outcrop locality
Edge of basin
Possible target areas
Dip (15°
Dip 15°-45°
Dip) 45°
Trend lines
Air-photo interpretation
Trend of lineation
Strike and dip of foliation (prevailing or unmeasured)
Trend of foliation (with prevailing dip)
Foliation with plunge of lineation
Mineral occurrence; Gp - gypsum
Granulite facies of metamorphism
INDEX TO 1:250,000 SHEETS
SCALE
1:1,000,000
MILES
KILOMETRES
W.A.
N.T.
QLD
S.A.
N.S.W.

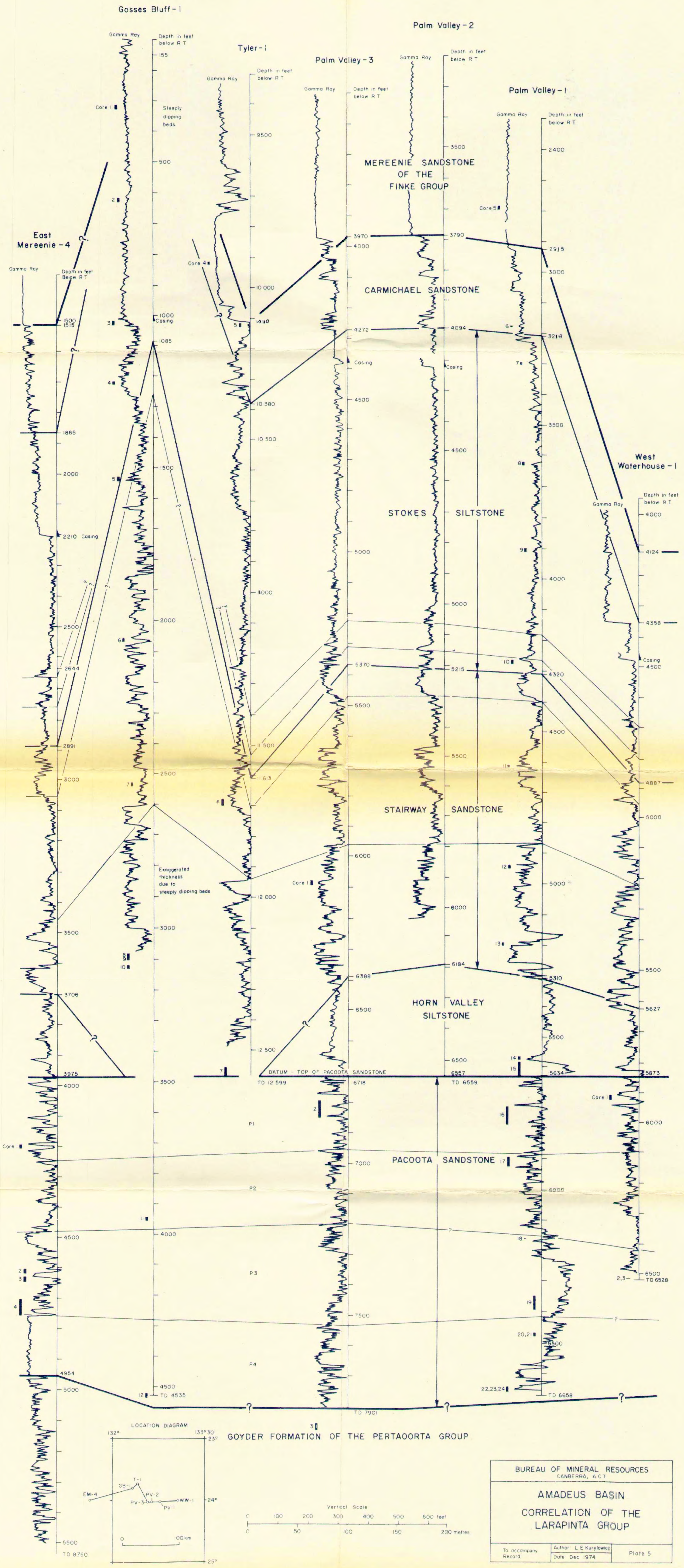


BUREAU OF MINERAL RESOURCES
CANBERRA, A C T

AMADEUS BASIN

CORRELATION OF THE LARAPINTA GROUP

To accompany Record	Author L E Kurylowicz Date Dec 1974	Plate 6



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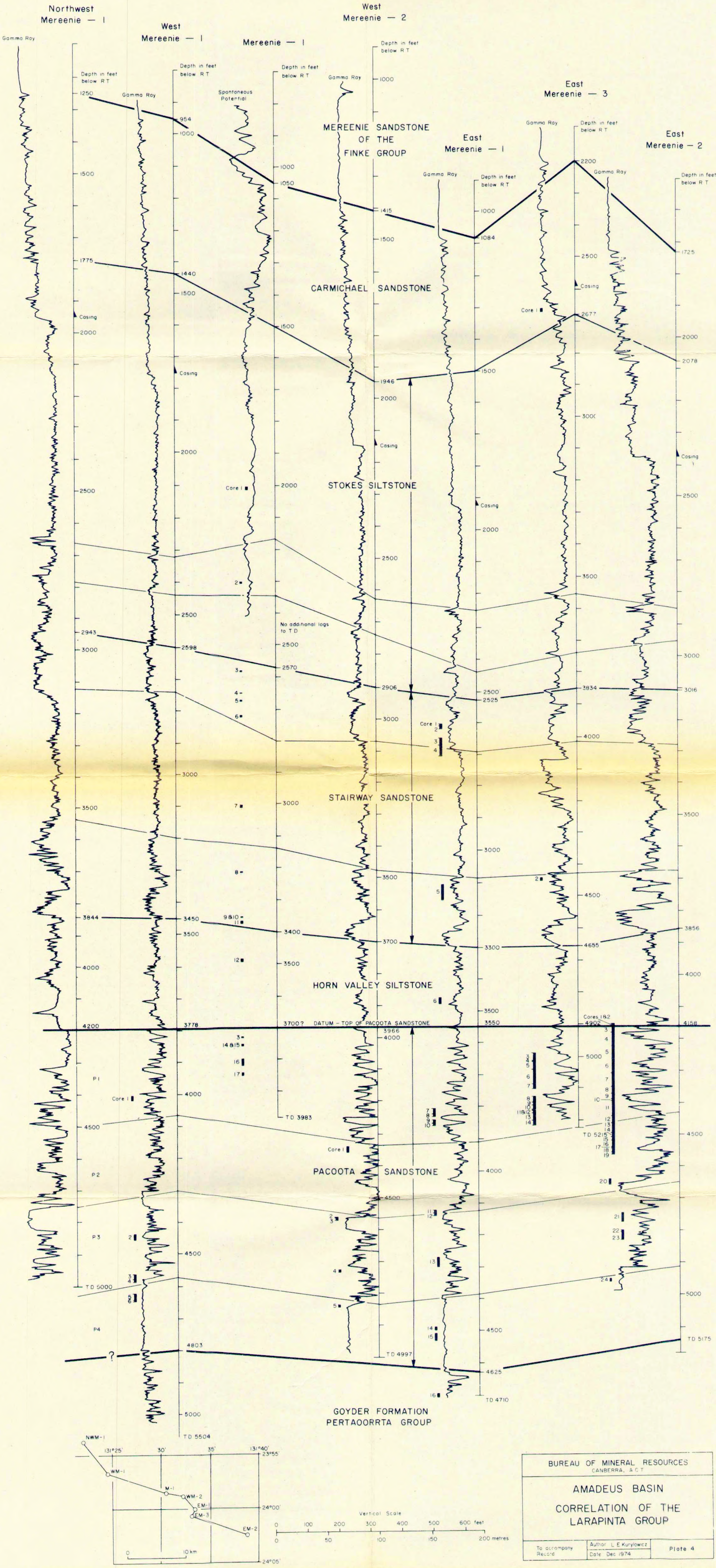
CANBERRA, A.C.T.

AMADEUS BASIN
CORRELATION OF THE LARAPINTA GROUP

To accompany Record	Author: L.E. Kurylowicz Date: Dec 1974	Plate 5



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CANBERRA, A.C.T.

AMADEUS BASIN

CORRELATION OF THE LARAPINTA GROUP

To accompany Record	Author: L. E. Kurylowicz Date: Dec 1974	Plate 4

23°00'
128°00'
129°00'
130°00'
131°00'
132°00'
133°00'
134°00'
135°00'
136°00'
24°00'
25°00'
26°00'
A —— B Structural cross-section line
□ Measured outcrop locality transposed
○ Well locality transposed
1:1000000
0 10 20 30 40 50 Miles
0 10 20 30 40 50 60 70 80 Kilometres
BUREAU OF MINERAL RESOURCES
CANBERRA, A.C.T.
AMADEUS BASIN
PALINSPASTIC BASE MAP
To accompany Record :
Author : L.E. Kurylowicz
Date : Dec. 1974
PLATE 3

BUREAU OF MINERAL RESOURCES
CANBERRA, A.C.T.
AMADEUS BASIN
GRID FOR THE PALINSPASTIC RECONSTRUCTION
To accompany Record :
Author : L.E. Kurylowicz
Date : Dec. 1974
PLATE 2
A — B Structural cross-section line
Measured outcrop locality
Well locality
1:1000000
0 10 20 30 40 50 Miles
0 10 20 30 40 50 60 70 80 Kilometres
Direction of max compression
23°00'
24°00'
25°00'
26°00'
128°00'
129°00'
130°00'
131°00'
132°00'
133°00'
134°00'
135°00'
136°00'

LOCALITY MAP - AMADEUS BASIN
CENTRAL AUSTRALIA
(after Wells, A.T., Forman, D.J., Ranford, L.C. and Cook, P.J. 1970, Plate 42)
Plate I